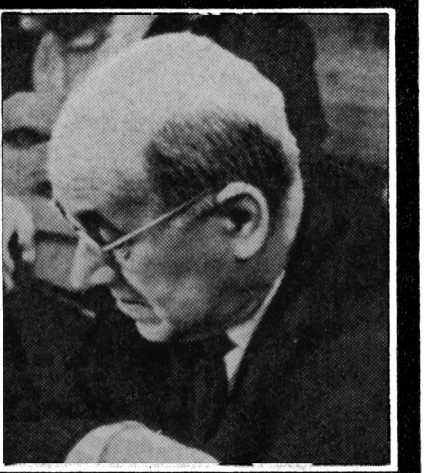
Aksel BERG
A Man of the 20th Century

Outstanding Soviet Scientists



I. L. RADUNSKAYA

MIR PUBLISHERS MOSCOW

AKSEL BERG
A Man of the 20th Century

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Outstanding Soviet Scientists

Aksel BERG
A Man of the 20th Century

I. L. RADUNSKAYA

Translated from the Russian by
Alexander Repyev

MIR PUBLISHERS MOSCOW

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TO THE READER

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His life, in essence, consisted of several separate lives.

And if he had only lived the first, or solely the second, or just the third of the lives, he would merit a biography all the same. Because each of his lives would be sufficient to make a full-blooded biography of an outstanding man.

In fact, the first life is the life of a nobleman, a czarist officer who sided with the Revolution and became one of the first Red navigators, first radio physicist and one of the fathers of cybernetics.

A tragic event nearly killed him. But he was destined to know a new fate, to become an admiral, an Academician, a Deputy Minister of Defence, a Hero of Socialist Labour. He was instrumental in developing Soviet radar science, one of the wonders of the century.

A myocardial infarction, several years taken away by diseases. But...

A third life begins. The 66-year-old Berg again puts up a fight, a fight for cybernetics.

It was not without good reason that his friends jokingly called the science cy-Berg-netics. A new life of the scientist. True, on the surface of it this life had no major upheavals, no exciting events — no battles and gales. If the earlier years is a novel of action, then this life is a novel of thought. It is a clash of ideas!

Some excerpts from his note-books:

"After the dust of centuries has settled down, we will be remembered not only for our victories and defeats in warfare or politics, but also for what we have accomplished for the future spiritual development of man."

"Nobody must be great or wise, but everybody must be honest..."

"Admiration for outstanding people produces natural desire to emulate them."

It is in this hope that I begin my story.

First

Life

The history of science cannot be bound
by the development of ideas—it should, to the same extent,
be concerned with living human beings, their
character, talents, social conditions, country and time.

from **S. Vavilov**

Chapter One

The Roots

Operation "Worm"

The Orenburg of the late 19th century. Small wooden houses. In narrow muddy streets roam hens, goats drowsily ruminate withered road-side grass. Meandering through dust, the streets converge in the centre of the town, near a stately mansion. For the old Orenburg the house is luxurious: it has a fountain in the yard. This is the residence of the chief of staff of the Orenburg brigade General Iohan Alexandrovich Berg.

Now the house is in turmoil. The house is being tudied up. The furniture has been translocated, the carpets rolled up, the chair-covers removed. Women scuttle about with brushes and pails. Also running about and getting in everybody's way are three girls. Now they vanish and reappear in a short while. They have put on conspiratorial air, whisper in a corner and suddenly, having heard something, sit down on a sofa. A fair-haired lady enters. She is petite, has lively beautiful eyes, high hair-dress. She is lean and slend-

er. For a short moment she stares at the girls, apparently astounded by their quiet looks, then some thought makes her gaze around, and she asks uneasily:

"Girls, where is Ksyusha? Why don't you answer? Edita, Dagmara, Margarita?"

The girls are exemplars of good behaviour.

Mother gives them a long suspicious stare, heaves a sigh and sails out of the room. She walks round the house and enters the hall, where the rolled-up carpets stand, and hears romping and groaning inside one of them. The general's wife rushes to the heap of carpets, throws them about, gets the largest one, puts it carefully on the floor, and unrolls... Her five-year old son makes his appearance from within the carpet. His blue eyes are full of tears, his fair hair is rumpled, his nostrils are red and flaired with rage.

Another half-hour and the house is shaken with sobs, the rattle of steps and cries reverberating throughout the rooms. "Ma!", "Mammy!" and Elisaveta rushes in the direction of the voices. Three girlish heads charge into Mother's lap. Mother raises the three tear-stained faces and tries to understand the reason of the crisis. After five minutes of bitter sobbing, the eldest, Edita, calls out indignantly:

"Ksyusha has fed us with worms."

"What worms?" asks shocked Mother.

"He stuffed a meat-ball with worms and gave us to have a bite at it, at first to Dagmara, then to Edita, and then to me," Margarita smiles through her tears.

"And the meat-ball he's stolen in the kitchen", adds Edita revengefully.

Mother looks at her daughters one after another and says quitely:

"You are to blame yourselves. Now you swaddle him like a baby, now you dress him up like a doll. And he is a boy, although the smallest. And a good boy at that, unlike you."

The girls are silent, and Elisaveta keeps her face straight. Thus comes to life the family legend about how was planned and executed the first strategic manoeuvre of the future admiral and scientist Aksel Ivanovich Berg.

Three Hundred Years Ago

Aksel's Father was a Swede; Mother, an Italian. For these people to fall in love with each other, their ancestors had

had to move for three hundred years from the north and south, from Sweden and Italy, to Russia, so that to meet and unite with the branches of their family trees.

The linearage of the Bergs can be traced down to Iohan Friedrich Berg (1746-1834), a Swede, a manager of the state mirror factory at Rokkala, Finland, and his wife Christina Elisabeth Helman (1769-1842). These were Aksel's great-grandparents, who had each lived long lives and left the son Alexander Konstantine Berg. He was born in 1800 at Vyborg, was a pharmacist, and married Emilia Charlotte Chenian (1805-1889). Like all Bergs they lived long — 85 and 84 years. Only Father of Aksel would break this tradition: he lived only 69 years — a combat general, he had taken part in a difficult Russo-Turkish war.

So all the ancestors on Farther's side were Swedes — the Bergs, the Chenians and the Helmans — but they had lived for three centuries in Vyborg, Finland, and so called themselves Finnish Swedes. Also at Vyborg in 1830 was born Iohan Alexander Berg, the father of Aksel. Later, when he would come to Russia, he would call himself Ivan Alexandrovich, and so Aksel was called not Iohannovich, but Ivanovich, sometimes even Alexei Ivanovich.

The Finnish Swede Iohan Alexander Berg became a Russian officer. After all, from 1809 to 1917 Finland was part of Russian Empire and Vyborg was annexed much earlier by Peter the Great. It is not surprising then that a native of Vyborg was sent to the corps of cadets at the town of Frederikshavn.

The pharmacist seems to have nurtured dreams of living to see his son to become a general (as a matter of fact, both his sons, Iohan and Karl, became generals) following in the steps of their ancestor, General Berg, who according to the family records had taken part in 1809 in the dashing invasion of Russian troops through the frozen Kvarken to Sweden and the resounding victory over the surprised Swedish army. The pharmacist copied an article about that expedition from a foreign newspaper. He scribbled it in so tiny gothic letters that now it is nearly impossible to make out and gave it to his son Iohan on the day he got his officer rank. And so more than forty years after the remarkable expedition the son read this unique document and made an inscription on the yellowed pages: "Copied by my dear father in his own hand on my commissioning day" and on his

deathbed he gave it over to his wife for his son, whom he saw for the last time at an age of six and, of course, he could not imagine that the boy would become a navy man and rise to the rank of admiral. Aksel would treasure this gift all his life. He would translate the text into Russian, put the original dated by 1809 and the translation dated by 2 August 1967 into an envelope and would inscribe it in his awfully incomprehensible hand, which was as difficult to make out as the gothic scribbling of the pharmacist: "Translation by A. I. Berg of the manuscript by Alexander Berg of Vyborg, grandfather on the side of the father resigned Russian Infantry General Ivan Alexandrovich Berg, who died in the town of Orenburg in the spring of 1900. The manuscript had been stored for decades by my late mother Elizaveta Kamillovna Berg, who died in Leningrad in the spring of 1940. It was given over to me in 1914, when I finished the naval corps and became a midshipman."

The historical account of the prodigies of valour of the 19th century General Berg got into good hands, but to whom bequeathed these sheets Admiral Berg? Alas, he had no son.

After graduation from the corps of cadets in 1851 Iohan Berg is the commander of the first company of the 1st Grenadiers of the Life-Quards at St. Petersburg, later the commander of a regiment in the Finnish town of Neischlot. After having participated in a Turkish campaign together with his friend, the famous General Skobelev, he was erecting hospitals at Peterhof, near St. Petersburg. Obviously, it was there that he encountered an Italian girl, Elizaveta Bertoldi.

In tracing the Italian branch of his kin Aksel was helped by his grandfather on Mother's side, Antonio Camillo Bertoldi. The grandfather wrote a curious book published in 1913 in Russia in German and entitled *The Last Thoughts of an 89-Year Old.* These turned out to be his last thoughts indeed, since he passed away in a year. His wife only outlived him by two months.

Berg would see the book when he would come to attend the funeral of his grandfather. There was a war. Aksel served at Helsingfors, and so he required a special permit for his leave. He would be in a great hurry back, but after the funeral would spend a whole night over the book. He lost it in one of the tragic moments of his life, together with another unique document: three volumes of diaries by Iohan

Berg, which Aksel's father had been writing all his lifetime, starting with 1845, when he entered the Frederikshavn Corps of Cadets. Also lost were many documents describing the life of the Bergs.

It has thus remained a mystery why the Bertoldis emigrated from Italy and how one of them found himself in Tiflis. Aksel recalled that the grandfather had begun the Bertoldi linearage from his great-grandfather Anton Bertoldi, a court musician of Count Marcolini. The musician travelled widely to engage singers for the Italian opera-bouffes. So he got to Dresden where he seems to have been so successful in engaging one singer that he himself got engaged to her, they married and he stayed at Dresden, where his son Andreas Bertoldi was born. He, too, was a musician: a violinist and singer. On his father's death Andreas moved to Turin where he played in the local orchestra. But when and why did he return to Dresden, where his son Antonio Bertoldi, Aksel's grandfather, was born? It is quite possible that having risen to the rank of the theatre director, he had brought his court theatre to Dresden for guest-performances, where he stayed and died. But this is just a conjecture. After the book has been lost there is no way of knowing the details. Nor is there any way of knowing whether those events have been connected with another relative, also Antonio Bertoldi, who quizzically combined the career of a businessman and revolutionary.

No explanation for this was forthcoming in the genealogical table, perhaps the most reliable one, which was quite unexpectedly supplied to Aksel Berg in 1964 by a Swede, Dr Himpel, via the Novosti Agency. Having read about Aksel Berg in *Sydsvenska Dagbladet*, Dr Himpel compiled the genealogical tree of the Berg kin.

In his pedigree, Dr Himpel traced the linearage of the Bergs down to the 1600s. This pedigree completely confirmed the two previous ones, compiled by Aksel's grandfather and uncle, and it included some additional dates absent in the earlier genealogies, the discrepancies being quite insignificant. So the progenitor of the Bergs Iohan Frederik Berg was said there to have been a book-keeper, not a manager, and a titular councilor at that. But it provided no satisfactory explanation for the strange wanderings of the members of the expansive Italian branch. In any event, it was confirmed that the grandfather Antonio Bertoldi, a mu-

sician and painter, really came to Tiflis where he married Margarita Karlblom, a daughter of a Lutheran pastor, a Swede, and on 14 May 1858 they had a daughter, Elisabeth. The girl had a romantic bent, she drew and liked music. When she was big enough to be educated, her father sent her to St. Petersburg, to the drawing school of Stigliz.

Soon the family followed her, and Antonio Bertoldi became a Lutheran parish pastor at Peterhof. I found it rather strange that a musician, a painter, a teacher of the Italian language, should become a clergyman. But an expert on religion explained to me that the Lutheran faith does not prohibit its priests from performing some secular duties. And so Antonio Bertoldi, a pastor, combined his services to God with his services to people: he gave lessons in Italian, violin and drawing. He even published a Sunday magazine for his parishers. His daughter, Elisabeth, or Elizaveta, also taught drawing.

At Peterhof, in the house of a pupil she met Iohan Berg, who had shortly before lost his first wife. Mary Künzel, yet a young woman, had died, as they said at the time, from Antony's fire, or, as we now say, from blood-poisoning, and so Iohan Alexandrovich Berg at 52 became a widower with two children.

Thus, Iohan Berg was already over 50 when he met Elizaveta Bertoldi. At the time she was not yet 30. They fell in love with each other, got married and went to Zhitomir to where General Berg was transferred in his military service. There their three daughters were born. In 1892 the family moved to Orenburg, where on 29 October 1893 (10 November in new style) their only son Aksel was born.

A Swede and an Italian

Three-quarters a Swede and a quarter Italian... What may come out of the combination? A medley of the Nordic and Mediterranian blood? A clash of ice and fire?

The relations of the members of the family, the atmosphere of the household—all bore the mark of the wellsprings of the Bergs. They were distinguished for their talents, enthusiasm and exhilaration. Everybody knew and loved music, played one of the musical instruments, and drew. The Italian effusiveness combined with the Swedish restraint. No baby talk, no sentimentality. Nonetheless, it

was not frequently in his lifetime that Berg encountered such family comfort and harmony, although he saught it always.

The tone in the household was set by the mother. She was a woman of wide learning, had a perfect command of French, German, Italian, English, and Russian, she painted and drew, carved in wood, embroidered in silk, played piano, and was a great reader. What is more, she was a born instructor. She had a way with each of her children, could be for them a confidante, a friend, an adviser.

"But there, at Orenburg, she was still very young", remembered Berg, 'beautiful, radiating charm. And even then she was the hub of the local society. She was an unusual wife of a general, she never was a philistine, a snob. A clever, educated woman, she was fond of Schopenhauer, Spencer, Buckle, Vladimir Solovyov and inculcated in her children a liking for speculation, analysis. She was at all times occupied with something, although we had servants, of course. She insisted that we did not fiddle about and did something useful. The girls knitted, embroidered, practised in languages or piano playing. The atmosphere was always relaxed, businesslike. Mother created a special style of family relations. And this was for me of immense importance. Character after all is formed in one's early years. This atmosphere developed in children the best assets. Nobody lied. You know, when I first found out that people may lie, I was shocked, I was not prepared for it. It did not occur to me for a long time that there may be bad people in the world. I don't remember any brawls and rows, any gossiping and drinking, except for the unhappy Alexander, my half-brother".

The family had its tragedy—the two children of Iohan Berg from his first marriage, Maria and Alexander. Unlike the children by Elizaveta, they were defective, having inherited from their mother a psychic disorder. This notwithstanding, Maria was a gifted pianist, she even took part in concerts. But she finished her years in an asylum in St. Petersburg. Even after her husband had passed away, Elizaveta often visited Maria and once she took small Aksel with her. He remembered Maria as a dreadful old woman, skinny and sick. She did not recognize her relatives and died in the hospital after a long disease.

Alexander suffered from rachitis, was mentally retarded.

At Orenburg he lived in a separate room, from where sounds of a flute were often heard. He was a clerk at a post-office, but he seemed to have got this post only from respect for his father. The parents tried to prevent Ksyusha from visiting Alexander's room. The room was usually full of smoke and Alexander was often drunk, which sometimes gave rise to scandals. Later on he got married and moved to another town. He died at an age of 60 from cancer.

Iohan Berg was a kind, soft-hearted person, although amazingly unpractical. His subordinates abused his kindness. He would at all times help somebody with money, bale somebody out of a trouble, petition for pensions and admittances of somebody's children into colleges and schools. Having no other income, besides his salary, he was perennially fond of something and spent money on subscriptions and things of no use to anybody. He collected rare trinkets and stamps. Adults viewed this as an eccentricity, but it tickled Ksyusha's fancy and conjured up visions of distant lands. And what beautiful fairy tales his father told him.

Aksel inherited from his father his love for books and drawings. The general collected books with splendid illustrations, and young Aksel for the first time saw in them a reflection of far-off worlds, unknown cities, mysterious beasts. He copied these pictures for hours, day-dreamed about travels, got used to planning and dreaming with a pencil in hand. From this time comes his inveterate habit of making sketches in his copy-books, diaries and logs.

Looking through the drawings of small Aksel one might, without turning to history texts, learn very much about, say, the Anglo-Boer War. One can easily imagine the popular response to that war, to see it through the eyes of a seven-year old boy from a Russian town thousands of miles away from the place. "The attack of the Englishmen"—a vivid youthful imagination pictures a file of dynamic figures with huge rifles. Four-coloured banners are flying, soldiers are pulling mortars,—the spirit of the bayonet. Soldiers on horseback, soldiers in the shooting range. "A Dragoon of the life-guards"—a dashing trooper on a muscular charger. And the Boers—holding their line, attacking, climbing hills. A wounded on an improvised stretcher, his comrades carry him, one of them falls down, another one shoots, yet another one lurches holding his heart. In large lettering the caption under the drawing says "Buren". And

then sea, ships. Ships in the margins of a maths copy-book, a Russian copy-book, a religion copy-book. Sketches and models. Ships entered Berg's life first on paper—from books and drawings—and obsessed his imagination for ever.

Aksel owed his love for music to his father. Iohan Berg had made many friends owing to his violin. They all delighted in listening to his duets with his wife, a splendid pianist.

In the drawing-room a kerosene lamp is on, producing an intimate semi-darkness. Aunt Yulia, Iohan's sister, brings in a samovar and various brands of jam. The General in his dressing-gown sits in his deep arm-chair. Near him Ksyusha perches himself on a bench. While his father narrates about the campaigns or concerts, he is drawing and in his own way travels in his fantasy with Father, and when Father finishes his story, the boy awaits the most fascinating thing—his father gets his violin from the case and starts playing. Perhaps in one of the dark Orenburgian evenings Ksyusha had his first lesson of violin playing. Ever since, wherever fate landed Aksel—a cadets corps or a naval corps, a ship of war or a scientific establishment—he would devote several hours a day to his violin, up until the tragic day when he would lose this ability.

A Genre Scene

In Berg continually popped up his early memories of the family, of early years and setting.

As to the setting, it was quite specific. It so happened that the small half-Swede and half-Italian first spoke in... Tatar. Yes, the first language mastered by Aksel Berg was Tatar.

Not far from the General's house was a round market place, full of horse-carts, heaps of goods, people, camels, water melons. Water melons were all over the place: on the carts and on the ground, brightly green, spotted like frogs—a feast for the eyes.

Camels are grunting, ruminating and spitting furiously. Muzhiks in all manner of outfits, bearded and beardless, in bast shoes and barefoot, all are making an outrageous hubbub. Covered with reddish juice they are eating water melons, and spitting sticky seeds, competing with the camels, and the slippery pulp is splashing under their feet.

On sale is whatever you like: Orenburg water melons—20 kopecks a cart, old coats, overseas gems. This is one of the nodes of the great trekking paths from Bucharia, from the Kaspian Sea, through the wilderness of the Ural steppe to the Lower Ural, to Samara, to the out-of-the-way corners of the endless Russia. Here, at Orenburg, in the realm of water melons and corn, is a sort of trans-shipping point. A resting-place, a bazaar, a caravanserai. And in the midst of this din, where camels are loaded and unloaded, in the hustle and bustle, stands Ksyusha, clinging to the skirts of his young, red-cheeked, black-haired nurse.

"What?" the two-year old boy points his finger at a camel and raises his inquisitive eyes.

"A camel," answers she in Tatar.

Ksyusha eyes her in admiration, she is the most intimate friend of his during his first two years. His mother has been short of milk and so this woman has nursed him.

"A camel", he repeats in the Tatar language one of his first words and reaches out his hand for the giant animal.

The camal is big as a mountain, but Ksyusha has no fear. In their household there are no cats, or dogs, and the camels are the only animals with which he makes friends.

"What?" he again points with his little finger, now at a water melon.

"A water melon, drop it," snaps the nurse. She is engaged in a lively chat with a young handsome boy. It is for this that she takes the kid along to this din.

The boy mutters this new Tatar word many times, torturing it and as if tasting it.

And in the evenings when the family gathers at home—the mother is playing piano, the sisters are embroidering and under Mother's guidance are practising English and French—Ksyusha, amid the laughter of his sisters, parades his vocabulary of spoken Tatar. Father and Mother, for some reason, are in no raptures over his performance, the sisters are making fun of him, Aunt Yulia shakes her head in sorrow—that's what happens when the kid is at a loose end and spends most of his time in the servant's room. And since nobody is going to praise him, nobody is going to pronounce with him these beautiful sonorous words, he walks out of the drawing-room and runs to the kitchen, where the maid, the nurse, his father's batman and his soldier-friends are having their tea. Here the boy encount-

ers complete understanding. Here everything is clear—after all, the young master was born in the Tatar town of Orenburg, and what other language but Tatar is he supposed to speak? The nurse, the maid and the soldiers are all Tatars, and so bit by bit the vocabulary of the General's scion becomes richer, and now he gabbles fluently in the melodious local vernacular.

The Death of Father

God knows what turn his fate would have taken—whether he would be sent to study drawing, as his mother desired, or would become an army officer, as his father desired,—if Iohan Berg had not died so early.

When it happened, Aksel was only six.

The entire winter of 1899-1900 the father had spent on an inspection tour. The brigade was quartered over the vast expanses of the Orenburg province, and the father had often to visit Zlatoust, Sterlitamak and other towns and places in the South Urals. The mother would accompany him. Strange as it was, the General, having spent in Russia more than 40 years, spoke broken Russian, whereas the mother had a perfect command of the language and helped him enormously on those trips. This inspection turned out to be the last for the General.

When Aksel was born, his father was Lieutenant-General. In 1900 he was promoted to the rank of Infantry General and at the same time dismissed. He learned about it having returned ill from the especially troublesome trip over muddy steppe roads. He was immediately sent to bed.

Berg clearly remembered the death of his father. His bed was in the bedroom of the parents. In the evening he fell asleep tired and excited by the scent of drugs and the presence of unknown people in white smocks. And in the morning he saw his father in coffin.

On the father's death the family sank into poverty. There were no savings, and the knighthood provided no income.

Since Iohan Berg came from Finland, where there were no estates, he became personal nobleman on receiving his officer's rank in 1851 and hereditory nobleman, on receiving a St. Vladimir order for a Turkish campaign. And so his children were hereditory noblemen, not landed aristocracy who possessed estates and serfs. No generation of the

Bergs had had any real estate in their possession.

Elizaveta Berg found herself with a small pension and a large family to support.

For a week she did not leave her room mourning for her husband, then she fitted her children out and went to Vyborg, to Aunt Yulia. The girls were enrolled in a school, Aksel in a German group, where children were believed to master the German language without tears. But the life would not take shape. The mother was seriously ill, Aunt Yulia could not handle the children. The girls, who were entrusted to take turns bringing their brother to the group, would abandon him half-way, and a seven-year old boy would roam about the streets on his own. Perhaps the only use of that unrestricted dealings with children in the streets was that he began to pick up some Finnish because in the town the majority of the population were Finns. In the streets and in families of some of his new acquaintances he also practised Swedish, a language he learned from his father.

But of course the situation could not carry on indefinitely, and so Elizaveta decided to take up residence in St. Petersburg, with her parents.

The Artist-Pastor

Early in 1901 the family settled down at the old Bertoldis', in their large flat at the Fontanka River, where they lived with their son Roman who had just graduated from the university and taught the theory of music.

Aksel was very happy with the arrangement. He was fond of his grandfather. They got acquainted at Vyborg, when Aksel was six, and Grandfather 76. Elizaveta and Aunt Yulia had rented a cottage on the shore of a fiord and invited the old Bertoldis. At first grandfather appeared to Aksel a bearded gnome from Anderson's tales, and in a couple of days they were already bosom friends.

The boy remembered his grandfather as a small, vigorous, despotic and, at the same time, kind and soft-hearted person. The old man worked hard and at the time Aksel was not admitted to him. We know already that Antonio Bertoldi managed to combine strikingly different endeavours. The effusive Italian was known by half of St. Petersburg. Once, when the ageing Aksel Berg visited Leningrad

and came to look at the house where his grandfather had lived, he encountered a couple of old women who remembered the kind Italian, their teacher.

So, in the last summer of the 19th century the boy found a friend, and the old man a companion for strolls and bathing, and an appreciative listener. True, they took some time in becoming intimate with each other. The barrier was by no means the 70 years of difference in age.

The snag was that grandfather and grandson were speaking different languages. The old man was a poor speaker of Russian, although he had long lived in Russia, he did not speak Swedish, although he was married to a Swede, but the boy did not understand Italian although his mother was Italian. The grandfather had a perfect command of German—he was born in Dresden—and the boy, apart from Russian, spoke a little Tatar, since he was born at Orenburg, and a little Swedish, which his late father had taught him from time to time. Aksel could offer to his grandfather his several scores of Finnish words, but Bertoldi had no idea about Finnish. Happily, this hindrance did not stop them from becoming friends; the grandfather got used to adapting to his 54 grandchildren, and this boy, the last one, turned out to be exceptionally compliant and devoted companion. In the long run, several dozen German words, which constituted the vocabulary of the six-year old grandson, appeared to be sufficient for them to get along.

The grandmother, confident that the old man and the infant would not stray far, did not trouble about their being out the livelong day, and so the two would roam in the woods for hours on end. They bathed to their heart content, angled, rowed, and the old man pulled a good oar and taught his grandson.

The two friends had explored the skerries and the neighbourhood to such an extent that when Aksel, a young naval officer, later fought in this locality, he was at home here.

They liked going for a walk along the wharf, to watch boats from warships to moor there. Sailors got to know the pair and welcomed them with invariable kindness...

The old man taught his grandson building models of ships, and since then the boy's room was filled with dozens of models, which he constructed from drawings in various books. The grandfather worked together with him—he could produce a beautiful ship with rigging and all from

some pine bark and cardboard, paper and wood ships. To do so, he only needed ten minutes and a sharp Finnish knife, which Aksel inherited and kept in on his desk.

The old man and boy shared love for drawing and music.

Aksel would sit for hours, nearly motionless, and watch the old Italian play violin or piano, or draw (he was fond of decorative painting, drew on porcelain, and painted landscapes). The grandfather started gradually to teach violin to his grandson. Aksel was making fast and sure progress. And his progress was so remarkable that the old man began to think of a career as a musician for him. It is here that their first conflict surfaced.

Sea

The boy who liked music, liked the sea even more.

When Ksyusha saw the sea for the first time, it seemed to him that it was the same Orenburg steppe, in a new disguise. And he wanted to enter it, as he did the waves of spring grass in bloom. But the sea turned out to be more captivating.

He had hardly dipped into the nearly icy water that smelled of immature astringent apples, milk and something else, totally unknown, that he was engulfed by a wave of euphoria, an acute sensation of victory over himself; through his body surged such an unexpected intoxicating hilarity that he gasped with delight and began to splash about and shriek with happiness. The boy dived again and again and began to cut capers in the water as a young animal, choking himself with spray and joy. He would like to embrace all of this green swell, the skies and the sun, which, unlike the scorching sun of Orenburg, was tenderly and piecefully stroking his skinny shoulders and head.

Aksel fell in love with the sea, and ever since, since the very first encounter, each time as he would feel the sea with his body he would experience the same exhilaration. It was the Baltic Sea that he liked, the Baltic sea-side, the fine-sand beaches. The Baltic shores, with long, huge dunes studded with amber and fine shells, with the poignant perfume of pine-trees and sea-weeds, with the perpetual—now ebbing, now waning—whisper of the pines nodding proudly to the sea and the sun. The Baltic sea, with the

smooth, gently sloping bottom over which you can walk for miles to challenge the seas, experiencing the gradual, ever ebbing and acute suspense of water touch. And when around one are solely waters, above one's head is only the sun, one loses contact with the rest of the humanity. He finds himself to be the only human being under the sun. Man, Sea and Sun. And in this union there is so much attraction and eternity, so much intoxicating joy...

The boy grew fond of early morning fishing expeditions. The old man and the boy would escape before a sunrise, when the whole household was fast asleep and the granny could not exhort them with dozens of "don't's": don't stray too far into the woods, don't venture too far into the sea, don't stay too long in the sunshine, don't, don't... Their fishermen-friends willingly admitted to their company the funny old man, making himself understood in God knows what dialect, and the boy, ready to take any job and proud of being admitted as an equal to that rough male party.

He took to night eel-fishing outings in launches, when they went out three-four miles off shore—the fishermen fired torches to attract eels and the fish were swarming around the boats, the men were harpooning them adroitly. He liked camp-fires in the dunes, when after a lucky hunt the tired fishermen were cooking fish soup, the best fish soup in the world, out of eels, and Ksyusha, his lips tightly pressed and his serious eyes wide open, listened to stories told by old fishermen about the ways of that fascinating fish, which lives in the Baltic rivers and once a year, in the autumn, some eels gather up into huge schools and make a single spawning migration to the Sargasso Sea to spawn and die in the warm waters near the equator, and the young return to the cool waters of European rivers. Ksyusha looked at the long, slender bodies of eels covered with amazing hide and day-dreamed of the days when he would grow up and would travel in a real ship after eels to a foreign sea with the name Sargasso, which came from a fairy-tale.

Unwittingly, the grandfather goaded Aksel's curiosity for sea by having acquainted him with his old friend Admiral Baron Mirbach. The old sea-wolf grew attached to the boy, he told him many stories about the cruises and sea battles he had taken part in. He had so enthralled Aksel with his stories that the boy set his heart on the sea.

Chapter Two

An Insipid Prelude

Last Pranks

Two years passed by, the children grew bigger and Elizaveta decided to establish her own household. She rented a five-room flat in Konyushennaya Street—the family occupied two rooms, the others were let to three teachers—an English woman, a French woman and an Italian woman. The pension was small, and the rent turned out to be of much help.

Aksel started his schooling. He attended the German parish school at the Lutheran Peter-Paul chirch (the Petrischule), which was founded in the time of Peter the Great and enjoyed good reputation. In his time the old Bertoldi had placed his daughter in the girls' department of the school. And now, to the boys' department, he sent Aksel. By the way, that same school would be finished by his future wife.

And now when life began to settle down, and when Aksel started his school and everybody was expecting that he would be doing fine, because he had been prepared much better than was required for the first form, a misfortune came about in Revel that had its most unpleasant ramifications in St. Petersburg. The husband of Elizaveta's sister, Anna, died and the widow sent one of her sons, Reinhold, to St. Petersburg, to her sister. Elizaveta, who had recently experienced the same disaster and sympathized with her poor sister, willingly accepted her nephew. He was about two years older than Aksel, was a perfect speaker of German and a voracious reader, and so Elizaveta decided that it would do no harm if her adolescent son had a companion. She perceived that a boy having no father and male company was lacking much in his upbringing.

But, alas, the "male company" did not live up to the expectations. The urchins were all too quick to twig that they could do splendidly without classes. As to arithmetics, Ak-

sel disliked it even before, and Latin was nauseating. To make matters worse, the teacher was a bore and outrageous pedant. What was more, the teachers at the school were all Germans, and Aksel's command of the German language was not that perfect.

The school thus became an ordeal for the cousins. True, they read much but wasted so much time on mischief that things were going from bad to worse at school. As a result, Aksel stayed down, and Reinhold was wisked away by another aunt.

Throughout the summer the family had been debating about what was to be done with Aksel next autumn.

The mother had her hands full with household chores, lessons and worries about the elder daughters. For a public school, on which the grandfather insisted, no funds were available.

There only remained one thing. A cadets corps.

The tempest of the Russo-Japanese War had given a good sound shaking to the trumpery of the Empire and taken down the army officer a peg or two. Elizaveta Berg, who was looking forward to see her son a great painter and who knew first-hand the drab routine of an army officer's life, only bowed before the decisive argument—in a cadets corps a late General's son would be taught at the expense of the crown. The only thing she could do was to choose the most liberal Alexander Cadets Corps, which enjoyed a reputation for its sound grounding in general sciences.

An Escape

In the autumn of 1904 Elizaveta Berg had Ksyusha put on a new uniform with glossy buttons and a belt-buckle—a real tiny man and a warrior—and brought him to Italian Street, to the Alexander Cadets Corps, where the boy would live away from his family. En route the mother had brought her son to a photographer, and, in the way of all the mothers sending their darlings to schools, perpetuated Aksel in all his cadet's glamour. He has a dress uniform on with shoulder-straps, which, as it were, strive to widen the boy's shoulders. The boy in the picture has the mien befitting not a cadet but a general, at least. One arm is "at attention", the other lies on a table, near a huge tome.

In another picture Aksel is in the same posture, only

now instead of a table he is placed near an arm-chair in which his sister Dagmara is sitting, a charming young lady in a white jacket, merry and sorrowful at the same time: the mouth smiles and the eyes are sad. Perhaps she pities the parting with her brother. But again Aksel has put on resolute air, he is ready to become a man.

But when the mother and sister had left him alone in the corps, anguish seized him for a long time. The anguish was added by a strange feeling—the feeling of uneasiness at being surrounded by males only. His last years he had been brought up without father—with the mother, aunt and three sisters, and he even had had no real boy-friends.

He then found himself standing in a rank of boys like himself, in the same uniform, with the same bright buttons and belt-buckles, which at all times and in all lands distinguished military from civilians, and some officer led them through huge halls and rooms. Never before had Aksel been to such an enormous and luxurious house. They were brought to a light room with columns and lines of beds with small lockers in between. And all beds and lockers were absolutely identical, just like the buttons and belt-buckles on the boys and the boys themselves in their uniforms. When the tutor, who represented himself as Piotr Petrovich Bratke, addressed them and told them about the life in the boarding-school, the rules of behaviour, their do's and don't's, Aksel, took such a fright that he availed himself of the first opportunity, jumped out of the window and ran away. But his escape was a failure, he was brought back to this male hostel, and the uneasiness and the distress that there was not a single woman around to console him overcame him yet more. The situation was, to use Berg's words, "as if there were nobody to speak to". He was very homesick. And ahead lied years of living away from the family, in public, living by command, in the rank.

The cadets got up at seven o'clock in the morning, formed up for morning PT exercises. Formed up for prayers, read in chorus the Lord's prayer, simultaneously took to their spoons in the mess-room—a huge hall that seated up to 800 men, where, however, ideal order and silence reigned. At each table sat about 20 people, among which a headman was appointed, who might be sent to cells if order was disturbed. To be sure, the boys could not let their mates down, and so their meals were dignified affairs.

Life without privacy oppressed Aksel. True, the boys had their home leaves on weekends, and for the first time he would storm into the house, completely out of breath, impatient to see his family. But soon there was no such joy any more—the mother got the post of a head-mistress of a gymnasium for girls in the Estonian town of Tartu and took the sisters along. She wrote to him warm witty letters, but those were just letters. Now Aksel spent his Sundays at the grandfather's but the grandfather grew older and more cantankerous, and he still disapproved of the future profession of his grandson. Sometimes one of his classmates invited Aksel to stay with him at his place over weekends, but this left the boy even more homesick.

The Legacy of the Petrischule

When the life at the cadets corps had settled down, it appeared not so formidable as in the first days. It was the realm of tidiness, discipline, but there were no drills and cruelty. The cadets—for the most part children of the military and intellectuals—seem to have acquired the notions of honour and decency with the mother's milk. Honesty was regarded as an indispensable quality, maintained by the entire way of life in the corps. Absolutely no theft. Absolutely no lies.

Second Captain Piotr Bratke proved to be a born instructor, who understood the psychology of the youngsters and treated them with warmth. He spent the livelong day with his charges, striving to make them friends and to bring out and develop the inclinations of each of them.

The corps had workshops, sports facilities, musical rooms, and so cadets could at leasure follow any of their favourite endeavours. Sports enthusiasts went to the training hall, and nobody coerced them to take up bench work or joinery instead. Music lovers could continue their education there. Aksel put down himself for lessons with a violinist, a musician from the Maria Opera Theatre, who came several times a week to the school to teach those who desired. They learned Bach and Hendel, Chaikovsky and Mozart. And before long Aksel was proundly occupying the place of the second-fiddle in the cadets' orchestra directed by Franz Schollar.

But his academic performance took long time coming

right—the legacy of the Petrischule made itself felt. Mathematics again came to a head.

A dwarfish colourless old fogey taught maths without imagination, but was all too exacting. Aksel was still doing bad, and they even were about to pronounce him dull. Who could imagine at the time that mathematics was destined to be the foundation of his future endeavour!

The situation with maths changed abruptly when sister Margarita said to Aksel that if he were to carry on that way he would never become a naval officer because mathematics lay at the heart of all naval sciences.

And now during his stays at home Margarita and Aksel would burn midnight oil sitting over sums. Soon Aksel caught up with the boys at the top of the class. But bad marks in German took their time in disappearing, although one may have expected more gratifying performance here. But... every one at school disliked the German teacher, the fat von Bursi. He was a pedant and swelled with pride, perhaps because he taught not only at the corps but also at the aristocratic Corps of Pages. When that bald-headed snub-nosed German entered a class, a show started to the accompaniment of the humming of pens, which were inserted into the slot of a desk and served the boys as splendid noise instruments. Bursi flared up, ran to the head-master and required that parents were called in. He especially hounded a blue-eyed fair-haired cadet with derisive eyes who prompted everybody. But his quite decent knowledge of German made him invulnerable. Bursi, however, soon revealed his weakness—the cadet hated learning verses by heart. And cramming poetry was Bursi's passion, he fancied that the way he could easier inculcate a liking for German poetry. Especially he tortured the children with Goethe and Schiller. Berg waged perpetual warfare with Bursi, losing points in it. Even many years later, on mentioning the German's name he would start muttering, nearly automatically, the longest passages of German poetry. He was amazed, he cursed, but still muttered.

"And still Bursi got the upper hand", his friends would banter, "He, of course, considered himself awfully good at poetry, and you, boys, block-heads."

"Yes, but with us he had much trouble. There were terrific rows. But I was guided not by mischief, but principle. I, even when a kid, believed that grinding is no method of

grasping a subject. Why litter the memory with unnecessary things? To delight in poetry by no means requires hammering it into one's head. I was awfully angry and had words with him. And I finished him off with prompts, he had thrown me out of class three times and then called in Mother, but I continued to tell him to his face my displeasure."

Berg is silent a short while, bringing back the far past, then he sighs and confesses:

"Obviously, I behaved improperly with him. A callow fledgling, and an old teacher. But I disliked him and all my life I used to tell people I disliked straight in the face about this. A troublesome feature."

In one of his copy-books, under a caricature profile of Bursi he wrote: "Courage to search for and speak truth, courage to be oneself—this is the highest degree of human dignity."

Courage is Infectious

Each year, after the Bergs had first spent a summer on the sea-side, the family came to one of resort places at Revel or Vyborg, where Aunt Yulia kept a boarding-house for ten persons. There they were sometimes visited by a distant relative Commodore Max Konstantinovich Schulz, an educated world-travelled seaman.

Schulz had been many years in charge of a training unit of divers and supervised all the diving operations of the Baltic Fleet. Sometimes in summer he took Aksel along with him to Björkö. There, in skerries, lied the training ship *Africa*. For the first time the boy was on a real ship of war. The spell of happiness lasted a fortnight. Aksel lived in a cabin with Schulz, he spent all time on deck and in boats. It was then that he learned how the sea could be harsh with man. During one of training divings he watched one of the freshers outfitted. All of a sudden a syren went on. Everybody ran to the descent and saw a young man who had just come up from the deep writhing in dreadful convulsions.

"Bends!" cried out the ship's medico.

The boy was rushed somewhere into the bowels of the ship. In the evening the uncle told the frightened cadet that the work of the diver is not all romantic tours over

the sea bed, encounters with marvellous fishes and silence and beauty not to be found on land. It is also full of dangers, and requires great experience, skills and, above all, cold blood.

"A diver must controll his each movement, calculate each step and not panic under any circumstances", told the uncle.

It was panic that nearly killed the novice. Having taken freight at something, he dropped the weight that holds a diver at the depth, and rushed for the surface, which almost cost him life.

"A yellow diver is an unreliable submariner, seamanship is a dangerous business, and once you decided to follow sea, you must harden yourself, cultivate your will and courage. Without these assets a man won't make a good sea-rover."

Aksel wrote in his diary: "The courage of the brave is infectious and it enthrals others."

Now he draws not only pirate brigs and victorious corvettes. A sinking armour-bearer lurches, shrouded in clouds of smoke. Wounded sailors haul their comrade into a boat. A shore battery showers a squadron of hostile ships with shells. A gunman falls at his gun.

And now among the drawings something especially peaceful—a huge column with an angel on top. But... to the right under the column a rank of soldiers. To the left, a crowd. Well, this is Palace Square! Only an eye witness could have drawn this. The drawing is dated: 9 January 1905. The Bloody Sunday. *

The Echo of War

Into the quiet cadet world were bursting redoubtable events. The time was pregnant with revolution, a war was in progress, the disgraceful Russo-Japanese War. Fell Mukden, went down in history the disastrous Liao-yang battle. Within the country waged workers' and students' demonstrations. Into the closed boarding-school tricked in rumours of the goings-on on the front, and those defeats could leave nobody unmoved. But it was at that time that

* Massacre of peaceful demonstrators that marked the beginning of the Russian Revolution of 1905.

special efforts were made to mold them as loyal subjects and blind tools of the monarchy. Whereas in the corps discipline and faith in the powers of the czarist regime were instilled, from the Far East came reports about the destruction of the Russian Baltic Fleet under Admiral Z. Rozhdestvensky and the fall of Port Arthur. The boys, formerly fond of Pinkerton and Robinson stories, started reading newspapers and magazines, pondered over the burning problems beyond the walls of the school.

Aksel suddenly discovered a fresh facet of the life of his grandfather. The old Bertoldi turned out to be an implacable opponent of the czarist regime who openly criticized the czarist orders on his half-German half-Italian language. In his heart the old man was a Carbonaro and was even a member of some society that united enlightened intelligentia. He, of course, was no Marxist; in his milieu they had no idea of Marxism, but they were intellectuals who understood that the czarism was the cause of the backwardness and decline of Russia and it would prove her undoing in the end if no decided measures were taken and the czar were not dethroned.

The rumours about the situation on the front, the fermentation of minds, the heated discussions in the families spread confusion and doubts in the young heads, and the tutors were having hard time keeping the unruly lot within the established rigid confines. And how could they possibly explain away to the cadets the import of the momentous events on the far front and close by, at home? They understood that when out of the walls of the corps, the cadets plunged into the thick of things. So on 9 January 1905 Aksel Berg happened to be in Palace Square and witness the shooting of a peaceful demonstration.

In the morning of the Sunday Aksel and his cousin left Konyushennaya Street and made for the Moika River. When they arrived at Palace Square, it was flooded with crowds, the people carried gonfalons, started manifestations. The boys hastened a bit, and suddenly they were passed by cuirassiers, shooting opened up, shouts were heard. The boys wisked into a gateway and from there they saw how the throng rushed, breathed with the same breast, they heard calls to fight, women with children in arms ran past them. When the crowds dispersed wounded and killed remained on the snow. The shocked boys ran home. For them

this was so unexpected and awful, so beyond their comprehension, that the nightmare of the day was retained by their memories as one of the most horrible events.

The Bloody Sunday triggered a wave to student riots. Unrest and strikes were waging as before. All this disrupted classes, made the cadets seek answers to questions that generally present themselves later in the life. The future appeared in the new light.

Chapter Three

At the Threshold of the Dream

The Naval Corps

What profession to follow? The Alexander Cadets Corps provided a sound training, much deeper than was required for military service, and many leavers entered universities, technical colleges, and civil service.

One time the Alexander Cadets Corps even fell into disfavour: it was too cultured an institution to somebody's liking. Ill repute of sorts.

Should he had remained at the corps after the four preparatory classes and finished it, Berg could have counted on obtaining quite a profound education enabling him to choose a career he liked. But the fifteen-year-old youngster had long shaped his plans. He had been longing for the sea and he devoted the four years at the cadets corps to prepare himself for the transfer to the naval corps.

He was making drawings and models of his first ships, the designs including ordnance, armour, colours.

Here are some comments of the naval architect Cadet A. Berg on the designs of the armour-bearers *Prince Suvorov* and *Tsesarevich*:

"The *Prince Suvorov* and *Tsesarevich* I constructed after a German squadron armour-bearer. The privite names of the *Prince Suvorov* is *Elizaveta,* of the *Tsesarevich, Margarita. Tsesarevich* was built in the summer of 1908. Both vessels, and two more, *Dagmara* and *Edita,* have been constructed out of (pine) bark stripped by me from trees near the town of Vyborg."

The young shipbuilder dubbed his first ships by the names of his mother and sisters, but this did not save him from failure—the vessels could not put out to sea.

Painstakingly and thoroughly he analyses his mistakes:

"The reason behind the failure, it seems, was the inadequate armour. I decided to provide the armour plating to reinforce the structure. I worked meticulously and long

for about a week. The job was an extremely difficult one, but I put my back into it. At last, the time came to test the ships on the water and we went to launch them. But once they left my hands, they capsized and floated with their bottoms up. I was in despair. After that I still decided to build one more vessel and came to the final conclusion that my bark ships would have to be armour-clad in a special way. It is over this that I currently reflect."

Already in the cadets corps Aksel took up astronomy and cosmography on his own, although these disciplines started only at the naval corps. But he was already well versed in star and constellation spotting and, if only theoretically, endeavoured to master the art of navigation at night, in the fog, out of sight of land.

Thus, contrary to the mother's expectations the cadets corps strengthened the boy's desire to become a seaman, not weakened it. And so in 1908, after the fourth form of the cadets corps, having passed the required exams, he went over to the junior class of the naval corps. Earlier he would often come the Vasily Island and stand long at the Krusenstern monument, situated close to the naval corps. Now he entered the abode of his aspirations by right, the impressive edifice, which has remained unchanged to these days. Time can hardly do anything to it—the building has been built for centuries.

At the naval corps were six companies, or six years of instruction. The sixth, fifth and fourth companies corresponded to the then fifth, sixth and seventh forms of professional colleges; the third, second, and first companies, to the three courses of higher professional colleges. The sixth company was, thus, the youngest, and the graduates were in the first company. Members of the youngest three companies were naval cadets, and of the senior three, garde-marines.

Moving on to the third company, the "kids" became men. The rank "naval cadet" was replaced by the long-expected "garde-marine". Garde-marines took the oath of enlistment and were considered to be in active service in the navy. Berg started his official naval career in 1911. He retired from the navy in 1960, and so he had spent 49 years in the active service. Of these, six years in the czarist navy, less than one year under the Provisional government, and more than 42 years in the Soviet navy.

The defeat of the Russian navy in the battle in the Tsushima Straits and the revolutionary aftermath in Russia made the czarist government pay more attention to the training of naval officers. Before the revolution the naval corps had been a privileged establishment with admission restricted to children of hereditary gentry only. Since 1906 the admission was opened to all estates. This was a forced move. Aristocrats stopped sending their scions to the navy, partly because of the chain of disgraces and partly because it was difficult at the time to make a career in the navy. But truly progressive people saw in the naval service a possibility for their children. It was more democratic than the army. Less drill, more humanity in relations between officers and men. Of course, among naval officers, too, one could encounter a martinet. For sailors the service was hard, but in the army it was worse.

By the time Aksel entered the naval corps the studentry had been renewed, the atmosphere had become more healthy and the quality of instruction had improved noticeably. More attention was now paid to mathematics, which was finding wide use in the courses of navigational astronomy, the theory of deviation of magnetic compasses, the theory of gun and torpedo fire.

Berg remembered: "It was in the naval corps that I was taught to carry out experiments and estimate the accuracy of the results obtained using a rigorous or approximate theory. This is now called data processing. The principles of probability, error theory and mathematical statistics were grasped splendidly because they were immediately put to use in navigation or gunfire. By the way, without those foundations, I would not have been able later to understand the gist of cybernetics. I was fond of all the sciences associated with the sea and the ship. I was never keen on gunnery, torpedoes and mines, but was extremely interested in astronomy, coast pilots and other navigation disciplines. I was looking forward to a career as a navigator."

Good and Ill

Berg remembered:

"In the naval corps the atmosphere was extremely favourable, the instruction techniques were better than in most of the institutes of learning of the time. Many of the techni-

ques are no longer efficacious, of course, but some of them might as well be restored. During classes the instructor did not ask questions. It is long known that the game of the instructor with the student, which is called questioning and which is ostensibly called upon to find out whether or not the student has prepared his homework is absolutely fruitless. And we had no such game. At classes the teacher explained new material, read lectures. And we solved problems or performed laboratory works. It was the practice that twice a week, on Tuesdays and Fridays, from six to nine in the evening, I took tests in some pieces of a course. For six years, at preset hours, I reported back to the instructor. I could preliminarily make an appointment with him for a consultation. If I had had any troubles, we had a talk so that everything would be in the clear. We never had any fears associated with examination papers: what question would be drawn, what part of the course? Nobody ever muttered: "If only such-and-such question may not come up, if only." It was a show-down, it never occurred to us to go and take a test if anything was not clear. Why? One could very well postpone the test by a day or two and clarify a question in peace. The teacher would give us additional material, work with us typical problems, and we never concealed from him our doubts; it was much simpler to solve them than to try and hide them. And, you see, it was quite reasonable. A course, any course, was broken down into a certain number of parts, and we took tests in them step by step, so that the final exam at the end of a year was essentially a synthesis of preliminary tests. The teacher, by no means, sought to baffle a testee with the most difficult question, to corner, expose, or humiliate him.

"By the by," Berg went on to say, "when I myself started teaching, I followed the same principle. I always made a point of dividing a course into parts and at appointed days I said to my students: 'Another part is over, and I'll test you. If you fail, we won't go any further. Would you, please, read up on the ground covered, and we will have a talk with you. No reports and passes, marks or whatever, we'll just talk in a friendly way and review this piece together.' And, you know, the students responded with enthusiasm. By the end of a year, when official exams started, they were a walk-over for my charges—they would have

already tested a dozen times their knowledge of the discipline step-by-step".

"Well, what was bad in that college"?

"Bad?" reflected Berg, "Well, I, for example, was nearly always broken. Mother could only allow me 75 kopecks a month as my pocket money. True, I was fed, clad and shod, and I only needed money for tram. And still, frankly, that was not enough. Other boys had an allowance of a rouble or even a rouble and a half. They were Croesuses. A bar of chocolate at the time cost 15 kopecks. For my money I could have had five bars, and then walked on foot. Well, I forgot, I couldn't have treated myself to so much chocolate: the cleaning of a pair of gloves cost 15 kopecks. We had to have white suede gloves on".

"Every day?"

"Certainly not, but by all means on Sundays, when we were let go home, and after tests on Tuesdays and Fridays. Here is another of the positive aspects of weekly tests—we had much more occasions, after all passing your test is always an occasion. And we went to the cinema—again 20-30 kopecks, or on the premises we had a movie or a concert, now free. We had our large sailors' orchestra. And in the amateur cadets' orchestra, in which I played too, besides garde-marines, were real musicians, who were in their active service. The orchestra played on Wednesdays on the gallery in the mess-room, and on other days we had our rehearsals."

The Hair-Splitter... Sez you!

During this period Aksel no longer had time for homesickness, since each minute seemed to have been filled. Always something interesting ahead: work in the model-workshop, or an excursion to a museum or theatre, or music lessons, or an interesting book in English, French, German or Russian.

And in his bed-side table lay the cherished note-book, into which, emulating his father, Aksel entered his thoughts and observations, copied pronouncements or excerpts from books that struck him, drew the profiles of ships born in his fantasy. That book absorbed his fondest dreams, it reflected the outlines of his character, showed how his personality matured.

When you leaf through the note-book, you feel that he did not forget what his uncle Schulz had told him and set out in earnest to mold himself, to cultivate will and courage. His imagination had been impressed by the heroism of the divers and he had remembered hard that a navy man must be tough and brave. The note-book abounds in dicta of the greats about courage, duty, devotion to one's endeavour, and self-sacrifice. No, those were not facetious aphorisms about love to be encountered in note-books of many a youngster. The notes of the young garde-marine radiate purpose and viewing his life as duty.

"A man who strives to carry out his duty truly, cultivates in himself the principles of manly character, achieves his destiny."

This was the first precept that Aksel put down for himself.

And further: "A man may only have industry, moderation, honesty and still rank high among the really worthy people." "Nobody must be great or wise, but everybody must be honest."

Yet further: "Without his principles, a man is like a ship without a rudder and a compass." "A man only then is of any value in this world, when it is known that he may be relied on."

"A true mettle cannot be achieved without effort. This calls for constant self-observation, self-subjugation and self-control. There may be temporal set-backs, trip-ups and various hesitations. One should struggle with difficulties and win."

One has a strange feeling comparing the youngster's strivings with real achievements. By testing youth with old age, by comparing what the compass of adolescence indicated with what the man had accomplished.

Berg wrote in the diary: "Childhood indicates manhood, like morning indicates day." All the aphorisms entered by the boy into his note-book, ones that attracted his attention, reflected as a mirror his intense desire to learn how to control himself.

Even in his declining years he continued working over this. He kept by his bedside a sheet with the words of Leo Tolstoy "A wise man is always quiet and merry". This was the first what he saw on awakening to a new day, and the last before falling asleep. And those who have dealt with

him at work or at home know how he strove to follow that rule, especially when making an important decision or presiding at an important meeting. How difficult is it to follow that wise advice, when clash dozens of characters, dozens of approaches—dedicated or frivolous, superficial and selfish. And although he himself recognized only complete devotion to duty, no compromises, and frankness, Berg always did his best to understand, reconcile and convince people, to direct their efforts, knowledge and experience to accomplishing a task useful for the country.

His note-books contain remarkable ideas about work. "Laziness is the bane of man", "labour elevates men and peoples." The hereditary nobleman writes with full confidence: "The duty to work lies with all classes and representatives of society."

It would be good to publish these youthful note-books specially for young generations. The young people, harassed by the crazy tempo of today's life, so need to perceive that it is important for a man to be alone at times, to reflect upon his or her life, upon experience gained by the earlier generations, to conceive of himself as not just part of society but also of the Small Universe, the creator of his or her own inner world, which is unlike any other on earth, which has never been and will never be.

The records of the young citizen are divided into the headings: "Character", "Courage", "Self-curbing", "Duty and candour", "Friendship", "Influence of books", "Influence of family", "Everyday experience"—just a code of laws in miniature. Here we even find "Influence of love".

I leaf through one book, a second one, a third—the same circle of questions, the same concerns. What is the reason behind this? Maybe my hero has selected at random some mottoes and all his lifetime followed them blindly, worn them as they were a favourite jacket or a tie? Or maybe out of a heap of wise thoughts engendered by the humanity he chose those which tallied with his predilections instilled imperceptibly by the family and the school? Or, else, maybe this is just a coincidence of tastes and inclinations, the merging of thirst and quench, the chance resonance of the same principles of life?

And where does such a striving to put down ideas of others come from? Here, is an explanation of the garde-marine himself: "Admiration for great people to a larger or

lesser degree gives rise to a natural desire to emulate them." That's it! The thirst to absorb all the best, all the most worthy, respect for the experience of others.

Really, how lucky for a young man to find a proper object for imitation. After all, imitation lies at the heart of any skill. Only some imitate ill, and others imitate good.

The young Berg disagrees with me, however. Judging from one of his records he is of another opinion: "A man should have guts to be his own self, not the shadow of another one." These two ideas seem to be in contradiction, but is it so easy to choose between them? Perhaps they complement each other. The young garde-marine seems to have given much thought to this. There is no denying that a man should be his own self, should be independent, should use his own judgement, express his own feelings, opinions and convictions. "A man who may not form his own opinion is a coward; a man who does not want, is a lazy-bones; a man who cannot, is a block-head," wrote Berg. But a man can be brought up, brought up by precept and example, cannot he? And under any circumstances the initial, driving force in this formative process will be imitation. Mankind have hardly a more typical and vital problem than mastering the skill of controlling the maturing of a child's personality, the skill of moulding it.

Endeavours of the young age shape a man. He evolves only following one path, from a dream to its accomplishment. The child seeks to grow up to be what he has admired from boyhood, to be embodied into the image he has cherished in his mind, one that at the same time inspired, fascinated and even a bit frightened him—is it really possible to become so brave as the hero in the children's book, as clever and generous? Is it really possible? Realization of a dream is one more full-fledged person, one more model for emulation, one more hero. Isn't Aksel's determination to follow the sea a good evidence of this?

The Idol of Young Officers

The time spent by Berg at the naval corps was an unhappy spell for the Russian navy. Having got after the corps into the active fleet, into the turmoil of a new war, Berg understood with especial clarity why he was so persuaded not to join the naval profession by his mother, grandfather and

many friends. (Only the sisters fancied to see their brother a mariner.) The truth was that the navy of Russia was not only unreliable, it was totally helpless. As a matter of fact, there was no fleet as such, only the remnants from the desaster of the Russo-Japanese War. There were neither good warships nor good naval commanders. In the navy reigned reaction, passiveness, frustration.

Only few thought of the restoration of the Russian navy. One of them was a naval officer who became the idol of Berg and his young comrades.

He was Admiral Essen, Commander-in-Chief of the Baltic Fleet. After a spell of decline Essen came as a breath of fresh air. A new ship-building programme was initiated in Russia. So, were built several successful destroyers, not very large but very manoeuvrable. This was a significant development. Most of the ships—among those destroyed at Tsushima and at Port Arthur—had been built abroad. At long last ships of war were again launched in Russia.

Essen's fame spread like wildfire throughout the navy. He attracted young officers, survivors of the Tsushima, the bearers of the best traditions; they backed him and rendered assistance in his Gargantuan undertaking of breathing new life into the navy.

The Baltic squadron became a model for the entire fleet and a centre of attraction. Essen loved youth and invited naval cadets and garde-marines to spend their vacations on board ships of the Baltic fleet. So during summer manoeuvres Berg was staying on a destroyer. Aksel made friends with the son of Essen. Naturally, the boy also wanted to choose a career of a naval officer. They could not be torn away from the latest equipment, devices and armaments, really first-class matériel for the time. Essen junior became a submariner.

Early in the war he was appointed the commander of the submarine *Bars* (snow leopard) and carried out two brilliant operations, but the sub did not return from the third cruise—it was sunk absurdly. It had been mistaken for a German submarine and rammed by a Russian destroyer.

Even after his son had died, Essen continued to watch over his son's friends and all the young men who were enthusiasts of the navy. All the six years of the naval corps had been blessed by this spirit. Garde-marines were craving for action. *Tsushima* by Semenov, a book that excellently

conveyed the spirit of the time, was a desk companion for them, it marked the paths to follow so that there would be no second Tsushima. It became clear that a naval officer should have perfect knowledge of hardware, navigation, principles of ship-building and a lot more.

After a spell on Essen's ships Aksel would come back to the school filled with added enthusiasm for navy and with new gusto pounced on modelling, astronomy, physics, and mathematics. Essen was a highly educated man, he spoke several languages, was a connoisseur of literature and arts and his entourage mostly consisted of cultured officers. This also infected the students of the corps. It was considered *mauvais ton* not to speak several European languages, not to be versed in the cultural life of the country.

Boys Will Be Boys

But was Berg really such a book worm, such a sombre recluse interested solely in drafting a code of rules for his life?

Let us leaf through several pages, skipping perhaps over a hundred of even more wise dicta than those we got acquainted earlier—flash by: "dreams, dreams, where is your sweetness?"—plenty of inquisitive and exclamation marks. Then comes the sentimental poem *Sailor's Wife* picturing a sailor taking leave of his beloved and her waiting for him. Then follows a schematic diagram of arrangement of players on a soccer field. Under one of the rings showing the players, the one on the right near the goal, stands "Berg", and further over the field we read "The team of cadets of the 4th company". Save God, boys will be boys.

Aksel Berg went in for football with abandon. He played in the corps and in the naval academy. He played the hazardous tennis, was a good skier, and was fond of martial games. A note-book contains a detailed planning of a campaign between the allied flotillas of Holland, Denmark, Norway, and Sweden.

Berg and his mates may have spent many an evening developing the plan of combat operations, and meanwhile, in meditation, he covered blank spaces on pages with comic drawings: a dandy mariner with a dirk and a pipe; some funny sailor with a cap in the form of a bonnet; a sailor giving a salute—one feels that he was taken aback

a bit and now his stance is so servile; and here is a dumb garde-marine with unnaturally protruding shoulders, obviously a dunce and fop, the caption saying "Airman Parfanenko in future".

And here comes a list of students with laconic notes: "Nevsky—chucked out in transferring to the 4th company from the 5th one, Mikulin—chucked out from the 5th company for insulting the honour of the naval corps"—no joke.

And what's this? "How to cook *bortsch,* navy fashion", "What's to be done to preserve meat aboard a ship". Just a book of cooking... "How to remove mazout spots." "The novel ways of mending socks"...

Summer Cruises

Having clasped in hand the recipes of cooking bortsch and removing oil stains, we, together with Berg will mentally come aboard a small sailing schooner. Not a single adult around, only youngsters in sailor uniform. We pace over the deck of the *Mariner*—the deck being furiously buffed with sand by a 15-year-old sailor, his face is from strain covered with beads of sweat and water, and the sun peers into the impeccably clean deck like into a mirror. On the captain's bridge, at the wheel, stands a garde-marine, too. We proceed to the galley—all the cooks here are boys, they are peeling potatoes, washing up, shredding cabbage, hacking meat.

"Those were wondrous cruises", narrated Berg, "and they were held each summer from 1908 to 1914. Two or three months garde-marines were cruising on training ships or first-line ships of the Baltic Fleet. The first cruising we, the juniors, had on sailing schooner. Those sailing trips inured us to the sea and dangers, taught us naval skills. On the sailing ships there, of course, was no modern equipment, and so our life was tough and strenuous. We were trained for the nautical profession in the same way as now they train astronauts—through labour, sporting and moral training. We were saddled with all the duties concerning cleaning and maintenance of the schooner. We took turns at the wheel, navigated the ship, performed all the operations with sails, cooked our meals, and cleaned our clothes. In addition, we were having our classes. We were taking pilot, navigation, Morse's code, the map of the Gulf of

Finland. We also had rowing exercises. And after the first two years, we were cruising in destroyers and cruisers of the active fleet, and were entrusted with new responsibilities in stoke-hold, as navigators, gunmen and signalmen.

"As a garde-marine I sailed on the cruisers *Russia, Aurora, Bogatyr,* the battleship *Tsesarevich.* As we grew, so did our responsibilities. At 16 and 17 years of age we already cruised on modern ships of war and acted not only as sailors but also as officers—directed gunfire and torpedo fire, worked with machinery and equipment, handled all types of fighting equipment, were responsible for pilots and navigation. We stood by for officers and had to make our own decisions, and if they were correct, they were carried out, and if not, they were discussed. And, of course, after the cruises we took tests. So was functioning some sort of natural selection of those fit for the sea. All aristocratic pretentions were knocked out of us decidedly. Those with delicate health did not endure; those who were subject to seasickness, were lazy or refractory were dropped out. For boys the conditions in the navy were rather heavy, however. Sleeping in hammocks in overcrowded bunk rooms, wind, cold, rolling and pitching, no endearments, no sentiments. Mother's darlings were having hard time. That's the sea for you. After that hardening I was already equal to the life on a submarine, although it was beyond all comparison. At that time the service of submariners was much difficult than that on a sailing ship. And so without the hardening that we, cadets and garde-marines, had received during our training cruises, it was impossible to serve in the navy. Our involvement in manual work was of enormous educational importance. This hardened us, taught us endurance, patience and concentration. Later in my life nothing seemed hard and difficult. No burden seemed excessive. And work with a book or in a scientific laboratory was just picknic."

The training cruises had another positive aspect. The boys got an opportunity to see the world, other countries. When a garde-marine, Berg had visited Denmark, Sweden, and most of all Finland—Abo, Vyborg, Björkö, Hanko, Frederikshavn, where his father studied in his time. Berg visited Copenhagen, where the garde-marines were received by the King. At ports the boys met with foreign training ships and mixed with their counterparts in a quiet friendly

atmosphere, chatting in several languages without interpreter. It so happened that they sometimes got involved in momentous events.

In the year when Berg joined the naval corps the heroic behaviour of Russian training ships in the Mediterranean made headlines. A force of training ships had received a signal from Italian shore radio stations about a disastrous earthquake at the town of Messina. Italy appealed for help. The Russian squadron decided to make for the Strait of Messina, where for several days sailors, officers and garde-marines were unearthing from debris people and animals, helped to erect provisional shelters and shared with people food and water.

For the novices, who had just entered the naval corps at the time, that was a good moral stimulation, they would come to take a look at their heroic seniors and at the bottom of their hearts they hoped in their time to repeat that prodigy of valour—hopefully earthquakes, volcano eruptions and time would provide an opportunity.

Berg carries on with his story: "If we throw aside the superfluous romanticism, we will have to recognize that the youngsters were often having hard time. By the time I put to sea on my first training cruise the situation in the navy had become aggravated. The government did not want any more to tolerate the freedom-loving spirit that reigned on the ships—too pregnant with revolution. And so the government started to tighten screws: they tried to make naval service more tough, so that officers and men had no time to wag their tongues and read improper books. Heavy manual work, less calls at ports, especially foreign ones, meagre food—this all, it seems, was supposed to strengthen the spirit of loyalty in future officers. The czar obstinately considered that the blame for the defeats in the Russo-Japanese War was to be put not on bad vessels, but on officers and men. He did not want to notice that the seamen had fought heroically. But as regards the political attitudes of the seamen he was not mistaken—the navy gave to revolution regiments of conscientious fighters and red commanders."

And still, as I gathered from Berg's stories, even the many years of training and practice were considered insufficient for a youth to receive his officer's bars. Having graduated from the naval corps the leavers were promoted to

the rank of ship garde-marines, sort of half-officers. Under the guidance of their superiors the future officers were acting as officers of the watch, navigators, gunnery control officers, and mine officers. Since each year the corps churned out about one hundred people, the garde-marines were commissioned to three or four battleships or cruisers, that formed a squadron of ship garde-marines. These units performed joint exercises and spent months in international voyages. And it was only then that the ship garde-marines were commissioned. The war, however, disturbed that routine, and the garde-marines were passed out earlier.

A Chase for a Prize

Berg passes from sail to sail and near one mast he holds off a bit, strokes its pride stem and gazes at the sail.

"This was my ward", finally says he, "main topmast staysail. I was in charge of it. And it gave me a fairly hard time. To take in and set it in any weather required a hell of skill. The schooner is rolling, the sail is tearing away and contriving to knock you down or at best to flap. And if something has stuck somewhere at the top you have to climb the ratlines to the mast, and then to crawl the yard—a horizontal beam to which the sail is fastened."

"And how did you support yourself?"

"Holding the rails. You crawl along the yard lying with your stomach on it and standing on ropes, and you work in that stooped position. The canvas is hard, and the hands are those of a boy, you are not used to that sort of work, and you are simply afraid. Then you crawl back along the yard and descend down the ratlines. On the other hand, we thus got used to tough maritime ways and learned how to manage not only sails but our nerves as well. This purpose was also served by punishments. Obstinate cadets were put on the so-called cross-trees—a platform on the mast. There they rocked together with the ship and conversed with the horizon. But naval cadets became Pegasus-winged topmen for life. Even on cliffs we ascended like lizards. I remember a cove near the town of Kotka on the Finnish coast. It was nothing special save for the fact that in the middle an island poked up, which we dubbed the Island of Observations. Each summer near that island moored our training barge—a dwelling place for senior garde-marines.

There, on the island, the garde-marines practised in astronomy and geodesy. The place was surrounded by other islands, rocky, with steep shores. We contrived to climb on those cliffs to commemorate for posterity our names. All the rocks were densely spotted with autographs of all those who had been there for astronomical observations. For the purpose, use was made of whitewash or red lead, to make the graffiti more resistant to weathering they were cut out in granite. It would seem that there was no place for a new rock lettering, but the dare-devils would search out nearly ungettable spots and, tried and signed their names so that they could be seen from a distance. Such, such were the joys...

After the first cruises Berg conceived a passion for sailing sport and achieved great skill in it; at any rate, he had long been a champion after he had won a race and got his first prize. Those were very responsible races. They were held in Finland in the Bay of Tvermina on six-oars. Anchored in the sea were training ships and garde-marines on their sailing boats had to sail round them following a predetermined path and to arrive at a predetermined place. And so Aksel Berg came the first and got his first prize, real naval binoculars.

This was a great honour, the prize was given to him before the rank, and real seamen, officers and sailors, saluted the garde-marine of the third company. Berg carefully copied the scheme of the races and treasured it his entire life. It should be recognized that the success went into his head and before long he nearly came to grief.

After a cruise he went to a Finnish town of Naantali, west of Abo, where his mother, a sister and Nora (his future wife) were having their vacations. The place is a beautiful sea-side resort, indented with picturesque skerries. Aksel was having his rest, picking up mushrooms, playing tennis, going yachting, and in the end he was mightily bored. Suddenly, he learned that the local yacht-club was planning a race. Together with his two cousins he decided to participate. Having snatched the first prize several days ago and feeling invincible, he appointed himself the helmsman and his cousins boatmen. And so, on an overcast day, with the skerries covered with fog, at an uncertain fishtail wind, two dozen yachts, taut with tension, gathered before the landing stage at Naantali. The starting shot went off,

and the yachts dashed on. They had to cover an involved winding route delineated by the Aland skerries. Fresh wind was blowing. That was no gale but an experienced sailor on a light yacht should have been on the alert. And since Aksel now considered himself an old salt and was burning with desire to outrace everybody—for once not in the training races where his rivals were garde-marines but here where he was racing with skilled yachtsmen, Finns and Swedes—he decided not to reef and to make full use of the wind. To be on the safe side, other boats reefed in.

Aksel's boat was racing at full speed, the wind furiously attacking the sail. The yacht overtook all the other boats and, heeling terribly, dashed out to the open sea where it was hit by a squall and capsized. The yacht tossed in high seas, took in much water and sank. The three brave boys, alone in the open sea floundered about in futile attempts to catch hold of the boat that was descending to the ground fast.

Not a single boat was in sight. Happily, the place was not very deep, and so the yacht offered them the top of its mast from the water, but since the sea was swept with large waves and the mast dipped now and then, all the three of them, of course, could not hold it without risking that last fragile rescue. Aksel was a good swimmer and, having left behind the cousins sticking to the mast top, fully clothed he swam for the shore. He was stiff with cold and his teeth were chattering when a yacht appeared out of skerries. A skilled Swede manouvered close-hauled, came up close to the swimmer who was in miserable shape, threw the end of a rope to him and hauled him in, then he also saved the other two boys. The saver had, of course, to retire from the race to bring the three failures ashore.

Aksel was unconscious. The last thing he remembered was a rope that had appeared from nowhere and which he grasped with his stiff hands. He was given a good artificial respiration treatment—he had swum about 30 minutes and taken in icy autumn water to excess. After that swim in the treacherous Gulf of Finland he had a long and acute bout of pneumonia. Besides, it was necessary to pay for the sunken boat, which cost more than 300 roubles. In the long run, the yacht was salvaged and brought back to the club. But still Elizaveta Berg had to cover the expenses of refloating and repairing the boat.

"She paid for the presumption of her irresponsible son," Berg had to confess, "well, I should have been more reasonable and, following the suit of the skilled seamen who were at home in those waters, to take in reefs, but... this was about what happens with me even nowadays," laughed grey-haired Berg, "I had to reef in, but there might have been no squall. I was aware that the Swedes were more experienced, and would have come the last or, perhaps, the tenth. And I was not happy with the prospect. You, see, the situation was demanding: I, a Russian seaman, was racing with Swedes, and I had to be the first, and so I capsized. In much the same way, even now sometimes it is necessary to take risks to win in just another 'race'... I know that my experience, rank and position oblige me to be ahead, and this is impossible without taking risks." Boyish audacity in him strikingly combined with common sense.

Comrades

In 1964 Berg received the telegram "Dear Aksel, congratulate you—exactly 50 years ago you and I graduated at the naval corps". The correspondent was one of the six survivors among the 120 graduates of 1914, Andrei Belobrov. There was a whole naval family, the Belobrovs: the father was an admiral, and three brothers were naval officers, navigators. The youngest one, Andrei, and Aksel had been friends and kept in touch. On the eve of the revolution they together entered the officers' navigating classes in Helsingfors. Later on, when Berg was a student at the electrotechnical department of the Naval Academy, Andrei joined the hydrographical department. And so they simultaneously graduated not only at the naval corps but also at the Naval Academy.

After the Academy Belobrov worked at the Hydrographical Board of the Navy. He became a professor, and up until his retirement he taught navigation and hydrography at their Alma Mater.

Aksel had another corps friend, much older than he, actually by three years, but at sixteen this was one sixth of the life. A hell of a difference... Heine is said to have remarked: "Three extra years in adolescence—that's strength".

Eugene Shvede entered the corps in 1904 and was al-

ready a garde-marine of the second company when he was appointed an *Unteroffizier* to a younger company. Aksel joined the company in 1908.

In the naval corps there had been a long-established order: the best students of senior companies, the most intelligent and disciplined, held in esteem by their mates, were appointed to the younger companies assistants to the tutors. Although an honorary distinction, this was a hard task, with a company having about one hundred men. True, companies were divided into classes with about thirty men in each, but even so many madcaps were quite a burden for staff tutors. And so to the younger companies were additionally assigned several senior garde-marines, one of them being promoted to the rank of *Feldwebel*, the others being *Unteroffiziers*. The *Feldwebel* and *Unteroffiziers* studied with their respective company mates, but their beds were in the dormitory of the younger company. Those boy-tutors were really people that enjoyed high respect, otherwise in that delicate role they might become objects of dreadful ridicule, which in a closed boyish group might have disastrous effects.

Shvede was one of those who had won universal confidence. When he first took up his complicated duties, he naturally sought support among the youngsters. Quite soon he paid his attention to Aksel Berg; who was conspicuous for his self-control, tact, outcomingness, and poise. He was always in good spirits. Those qualities were of value in a juvenile group, which generally included a wide spectrum of characters: nervous ones, quick to fly off the handle, mischievously desperate, and impertinent. For the new *Unteroffizier* Berg was a happy find. Eugene and Aksel had a friendly chat; it appeared that in intellect the "kid" was quite advanced in his development, he read much, knew and loved music. Shvede was glad to find that his new pal was a lively person, with imagination and humour, not "the top of the class" with a narrow horizon, but a cultured and thinking youth.

It so happened that their mothers were old acquaintances, in their time they visited each other and made friends thanks to their fathers, who had been bosom friends of long standing.

Eugene's father was a navy man as well, the captain of a ship, later in his life he commanded an expedition of

ships to the Yenisei River. At the time the great Trans-Siberian Railway was laid, and the rails for the project were transported through the Yenisei, on ships of war.

Shvede's ship was a wheeled one, built in England. Shvede had travelled on it through the entire Yenisei and discovered an unknown bay, which is now called the Shvede Bay. In one of those trips Shvede caught cold and died. The family waited for the father for Christmas, but in vain. At the time Eugene was only three.

Nearly all the Shvedes were seamen. Eugene's uncle was one of those who distinguished themselves at Tsushima, and the Russian writer Novikov-Priboi portrayed him in his novel Tsushima as Sidorov.

As with Aksel, the main formative influence was his naval relative. The boy often called on his uncle at Kronshtadt, and saw him off to Port Arthur, when the uncle departed as the senior officer of the squadron armour-bearer *Orel.*

Shvede's career was also predestined by material considerations: the mother received a small pension. In the corps he was greatly influenced by the outstanding scientist Shokalsky, whom he regarded as his don. Shokalsky was an honorary academician, a major oceanographer, he was associated with a galaxy of geographic discoveries. The research ship *Shokalsky* is one of the best in the world. And at that time Shokalsky taught at the senior classes of the naval corps. Later he was the dean of the hydrological department at the Naval Academy and Shvede was his deputy.

When I met Eugene Shvede, he was an Honoured Scientist of the RSFSR, a rear-admiral, a professor.

He said: "You know, I think that Aksel and I were lucky. By way of milieu and companions. We studied at the naval corps in an extremely interesting period of the history of Russia. Revolution came to a head, and we, boys, were very excited by reports about events on the ships. About many of them I heard from my uncle. Here is one of them.

"To *Orel* was commissioned Novikov, the future writer Novikov-Priboi, who already at that time was known for his revolutionary attitudes. The czarist secret police in an accompanying paper required and requested that the officers spied on Novikov. My uncle called him in and said "Read! I received this paper. Look out." And the reason was not so much the principles of that officer. Such was

the spirit of the entire navy. Careerists were detested. When I served on the *Sevastopol*, we were once repaired at Kronshtadt. Two officers were allowed to go to St. Petersburg, on leave. After having toured the city they made for Czarskoje Selo. And they found nothing better than to satisfy their curiosity by asking a policeman 'Where does Rasputin live here?'. The policeman answered 'Get on. It's none of your business'. They came back to Kronshtadt with spies in their wake. The spies asked for the captain. But the captain answered 'I've no idea, haven't seen the officers. And keep away, no strangers are allowed on a warship'. To be sure, the officers behaved foolishly and they were given a good dressing, but the captain couldn't betray them to the authorities or even allow to question them. This was almost impossible in the army. The navy was more freedom-loving, ships travelled abroad and seamen met various people.

"The life on a ship has always been more family-like than in the barrack-room. It brings officers and men closer together. Army officers never lived in the barrack with the soldiers, but a ship is a common home. When an officer appeared on deck, no sailor jumped up, otherwise deck hands would have to stand at all times. True, there were characters among the naval officers who bullied men, but they were generally despised and as a rule finished badly."

Berg commented: "I believe that for the progressive, really patriotic intelligentsia there, perhaps, was no question of "for what cause"—the czar or the revolution. There was no other moral way out, but to be for the revolution. For Russian intellectuals it was natural to side with the revolution. Those were not by any means active revolutionaries. Many then even had no idea of the Bolsheviks. But to stand for Russia meant to stand for the revolution, no other path really. The czarist Russia died out, fell to pieces, perished together with the miserable czar. The scoundrels, who in 1917-18 fled abroad, don't count. True patriots remained at home, in Russia."

The general spirit of a time can often be better perceived by specific examples. Hopefully, I had not offended Shvede by my question:

"I know why Aksel Berg sided with the revolution, but what were your reasons?"

"You see, the sunny side of a street is always more at-

tractive than the sombre one, and besides at the *Sevastopol* we had a very good captain. He helped many officers to select the right path in life. He would say to us that it was stupid to emigrate, we should build a new life. No physician can help a patient if the patient does not want to recover. And, besides, an intervention is no physician, as the foreign powers tried to persuade when they undertook the task of 'curing' Russia. Russia had to receive for a new life on her own. And this was only up to the Russians, up to us."

Those are details, contours of the medium, sketches of portraits of people who were Berg's company and somehow or other left a trace in his life, large or small. Even a simple tiny piece of shingle on a beach grinds and shapes its neighbours.

Feldwebel of the First Company

Time was flying by. And with it was growing the influence of Berg on his comrades. He was nearing his manhood; now a garde-marine of the second company, he was appointed a *Feldwebel* to a junior company.

Once I got acquainted with one of the former charges of Berg, Veniamin Kornilov. His father, Nikolai Kornilov, taught navigation at the corps and was a teacher of Berg. Aksel came to Kornilov's and danced mazurka at parties organized by Venja's parents for the elder sisters and their girl-friends from the gymnasium.

Veniamin Kornilov reminisced: "I looked up to the partners of my elder sisters as at some heavenly creatures, and when the time came for me to enter the naval corps my junior tutor turned out to be Berg. From the very beginning Aksel won our admiration and respect. His way of dealing with us made it clear to us at once that, despite his youth, he could have his own way, could retain self-control under any circumstances. When facing the rank of cadets, who with their merriment and giggles, strictly forbidden in the rank, would make anybody laugh or lose control of oneself, Berg always managed to keep his face straight and, believe it or not, during a year I had only seen him fail a bit and smile perhaps two or three times".

Kornilov was silent a moment, then he added:

"I remember an incident in which Berg preserved his

Olympic calm, while all the corps, all the teachers and students were frantic. An extraordinary thing happened. Once the tutor ran into the class-room and announced, 'In our company is enrolled a new cadet, a Prince, a nephew of His Emperatorial Magesty Nikolai the Second'. All hell broke loose, like at a fire. Our company commander, and he was my father, ran to the corps director Admiral Rusin for instructions: what ceremony to follow. Whether to receive him as a member of royalty, or as a common mortal? The Admiral was known as a liberal. 'Of course, as a common cadet', he said.

"The new cadet was brought up to the main entrance on a pair or trotters, surrounded by a glamorous suite. Director himself ran out to meet the Prince and ushered the new cadet into the corps, where his future mates, even without a command, stood at attention. Berg commanded 'Attention' and Nikolai Kornilov, as agreed, approached the Admiral with his report. But Rusin brought the 12-year-old boy into the front and so Kornilov had to report to him. But the report had been preliminarily compiled for Rusin!

"Farther was shocked, he floundered and hardly managed to finish, then he brought the 'ordinary' cadet to the left flank and placed him according to his height. The director congratulated us with the enrollment into our company of the Prince and dismissed the rank. Berg gave the command and the new cadet together with his suite was removed from our life. After the procedure Father rushed to the officers' room and sat there holding his head: what would come out of it? But Berg only shrugged and smiled ironically.

"But reserved and silent Berg was only on duty," Kornilov went on to narrate, "At leasure he was a merry and good comrade. When reprimanding us, he never raised his voice, but with his serious, stern glance commanded respect and obedience. Always neat and austere to himself, he made even the lax ones to straighten out. It somehow happened that we did our best to imitate him and even contended for his approval. What especially surprized the senior tutors was that the boys carried out all Berg's requirements, although he extremely rarely, only in extreme cases, made use of his right to punish us.

"To be punished by an extra duty or to be put to wall by Berg was an enormous disgrace with us," added Kornilov,

"because the punishment came from the *Feldwebel*, and from Berg at that, who hated to throw about punishments, and if still it was incurred, it was with good reason. But upbringing by punishment is a tempting method. Guilty—go to the cell, simple or strict. The inmate was not let out even for classes, and for walks, and not allowed to go home on weekends. He lived only on bread and water. By and large, Berg's position called upon him to exercise especial tact.

"When we were transferred to the fifth company, we saw our Aksel not the *Feldwebel* of a junior cadet company but the *Feldwebel* of the eldest company, the first garde-marine company. This was an especial honour. But we were so sad to part with him, although we were proud of the fact that it was *our Feldwebel* who deserved the honour, so rare in the corps, to command his mates garde-marines, not us, boys. This post was generally reserved for the best of the best in academic progress, in discipline and in intelligence. Smart and serious in his new uniform—not a sailor's peakless cap but an officer's cap, not a simple garde-marine's sabre but a naval officer's sword—he paraded before us on the first day of the school-year at the head of his first company."

That was the last year at the corps, among the graduates pranks became fewer, everybody was sitting for the examinations and studied much. By academic record Berg was at the very top of his company. For him it was not only a matter of honour.

At the corps was an old tradition: the first graduates were rewarded by a circumnavigation. Berg was about to pack for the voyage, but history decided otherwise.

Chapter Four

The Stormy Spring

The Impotent Ruler

Russia had barely time to raise her wounded head, when from a cloud swelled with international conflict came the thunderstorm of a world war. Ship garde-marines, fresh from the corps, had to be commissioned to ships of war in the active fleet. Why? Who were they going to give their lives for?

By that time Nikolai II had been so unpopular that the news that the corps graduates would be brevetted by the czar himself did not impress them in the least.

The ceremony took place in early August of 1914, when the war was already in progress. It elicited no patriotic fever in the young officers. The passing-out ceremony had been organized in haste and it was not a solemn event at all.

The garde-marines were brought to Peterhof. Nikolai II with the Empress strode hastily before the rank, congratulated the youngsters in a hurry and immediately left. Then in the open there was a buffet. The atmosphere was painful and boring. The young officers had already been assigned to war ships and expected nothing good from the fate. The moods were gloomy, the eyes sad or angry. The function arose no enthusiasm, and even no curiosity, just as Berg experienced during his first encounter with the czar. Although it had been quite recently, about a year ago, everything had been quite different.

... In the famous Czarskoje Selo, in the former *lycée*, where Pushkin had studied, was situated an old court church. In the spring of 1913 to the Easter matins where the royalty and the court were to be present, was also invited Elizaveta Berg (then the head-mistress of the Czarskoje-Selo female gymnasium) with the daughters and the son.

Aksel was standing motionless at attention and even stopped breathing from curiosity. The royal family made

their appearance accompanied by the courtiers. What Aksel saw startled him for ever: the sovereign cut an exceptionally miserable figure—a twisted midget with a flat, inexpressive face. An utter nonentity.

Whereas the first encounter with the czar evoked in Aksel interest, and the second, indifference; the third one left behind the feeling of rage, since it brought a disaster and might give rise to a tragedy. It occurred in another year, in the heat of war. Berg had already been in the active fleet on the battleship *Tsesarevich*. The ship had just escaped from the Aland skerries, those goddamn skerries with their horrible channels. But at the very exit to the open sea the battleship captain had made a mistake. The ship had deviated from the narrow skerry passage, touched ground and got a hole. Of course, the crew had immediately fothered, but there had been no question of further participation in the operations. The only alternative had been to sail to Kronshtadt to be repaired at a dry dock.

It was the summer of 1915, defeats on all fronts, and so it was decided to cheer up the navy by a meeting with the czar. Nikolai II with the Empress came to the battleship. The officers and men stood in a rank on the upper deck, the royal couple sauntered along the front. Then they came up to the captain and were surrounded by the officers. All of a sudden, out of the bow holds belched rolls of black smoke. A fire of a battleship in a dock, in a nearly peaceful situation! But a ship of war is crammed with ammunition and may explode. And not only the *Tsesarevich*, but the dock and everything around.

The czar with his suite vanished into thin air in a jiffy, the crew rushed to fight the fire. Nobody was hurt but a furious investigation was started. Somebody was arrested, revolutionaries were looked for—they were thought to have organized an attempt on Nikolai's life. No culprits were found but the ship was put on the black list. *Tsesarevich* was repaired all anyhow and again sent away to the Aland skerries. She was no more admitted to Kronshtadt.

A Charm

On the passing-out day Elizaveta Berg gave to Aksel the family relic, the description of the historic dashing crossing of the frozen Kvarken by Russian troops. I have already

mentioned that the document was held by the Bergs in great esteem: Aksel's grandfather gave it to his son Iohan when the latter got his officer's bars in 1851. And now Elizaveta, by the will of the late husband gave over the valuable charm to her son on his memorable day in May of 1914.

In our nonsentimental times this seems to be an event of little importance and even a bit funny—who in this day and age puts much stock in a legend, a piece of paper?—but for Aksel it was an occasion. He became a man and understood the price of fortitude, a symbol of which he now got from his ancestor, General Berg, who had taken part in that compaign. In any event, he took the ancient document as a relay of generations and decided to treasure it all his life.

Young Berg, ready to do his duty, was firmly determined to be worthy of his name. That was why in one of the last peaceful evenings before his departure to the active fleet he was moved reading the simple story about an old war between Russia and Sweden, whose outcome had been predetermined by the valour of the Russian soldiers.

"It took place in the Gulf of Bothnia, which at first widens gradually on either side at its beginning near the Aland Islands, then narrows between the Finnish town of Vaasa and the Swedish town of Umeå and forms a straits about a hundred verstas wide, called Kvarken. In the middle of the straits there are several groups of islands, for the most part consisting of uninhabited unassailable cliffs. In summer, the Straits of Kvarken—because of the many shallows and uneven bed—is hazardous for navigation: in winter it freezes completely and thus links the two opposite shores. But this winter path is extremely hard and dangerous. The ice abounds in crevices and openings slightly covered with snow. Frequently a sudden storm destroys the unreliable bridge and drives the ice to the open sea.*

"Before General Barklai-de-Tolli took command of the Vaas Corps, his predecessor Lieutenant-General Prince Golitsyn ordered ten specially chosen Don Cossacks to cross the Kvarken to collect intelligence about the enemy. Having overcome all the hardships, the Cossacks came on foot over the ice to the Haddon Island, on the night of 15 Feb-

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* The *versta* is an old Russian unit length equal to 1.0668 kilometres.

ruary they ambushed a Swedish picket, took it prisoner and returned with the report that it was impossible for a whole army corps, with artillery and all, to carry out the crossing. This tallied with the opinion of the Swedes and Finns."

Although Finland was mainly subdued during February of 1808, no peace treaty had been concluded and Sweden did not recognize the annexation of Finland by Russia.

The main hope was pinned on the crossing as a surprise for the enemies. But Prince Golitsyn, the commander of the Vaas Corps, had reported to Emperor Alexander I that the crossing was impossible. Barklai-de-Tolli, appointed instead of Golitsyn, also wrote in his report that it was an impossible undertaking. Barklai's report of 23 February 1809 was answered by the Military Minister Arakcheev: "A general of your talents needs no instructions. At the moment I would like to be in your place. There are many ministers, but the crossing of the Kvarken is only up to Barklai-de-Tolli."

And although Aksel did not know yet that he would have to fight not far from those places, he was absorbed in the dramatic tangle of circumstances, the collision of duty and impossibility to do it.

What would he feel in the face of danger? How would he behave under circumstances that call for especial qualities in a human, a "rise" over one's own potentialities? It was this acute collision that fascinated him.

"The disposition of Barklai-de-Tolli before the campaign was as follows. The troops were divided into two units. The first one was commanded by Colonel Filippov, the second by Major-General Berg. Under his command were grenadier and musketeer regiments, 200 Cossacks, and six cannons.

"The units selected gathered on the Kvarken Islands and waited for the supplies and victuals. The day of 7 March they spent in a camp on an uninhabited island of Valgrund 20 verstas from the shore. Only the boundless snow wastes and the granite rocks of Eiland were in sight. Everything looked like a grave stone of dead nature. Not a sign of life, no trees, no bushes—nothing disturbed the glum of the hopeless wasteland. Winter reigned with all its horrors. The troops had to suffer the frost without fire and tents. On 8 March at 5 o'clock in the morning all the troops on the Valgrund Island set out on their expedition. The first unit led the way, in the second one—with General Berg—was

Barklai-de-Tolli himself. In the rear were artillery and reserves.

"The very first steps over the frozen sea revealed obstacles that seemed unsurmountable. A strong gale that had raged in winter had crushed the ice in the Kvarken and piled up ice-hummocks. From a distance those ice mountains were an unusual picture: it seemed that huge sea waves froze in mid-swing. Difficulties mounted up with each step. Now it was necessary to climb ice mountain, now to go round them, and now to struggle through deep snow drifts that covered the ice. Exhausted and perspiring despite the bitter frost, the soldiers trudged on, and a strong wind from the north made it impossible to breathe and paralysed soul and body. It evoked fears of turning into a hurricane that would break the ice under feet.

"At long last, after an exhausting 12-hour march the corps of Barklai-de-Tolli reached off-shore Swedish islands.

"It was decided to attack Umeå from two sides. The first column was ordered to proceed straight on to the shore, to contact the enemy there, distract their attention and, without being involved into a major combat, buy some time for the second column to arrive. And so, at midnight the second column with Barklai-de-Tolli and Berg started to march to the town. All the difficulties encountered by the soldiers previously now seemed to be child's play as compared with what awaited them ahead. Without any sign of roads, in deep snow and bitter frost the Russian troops covered the ten miles in 18 hours. When they arrived at the mouth of the Umeå river the soldiers nearly could not move. Under these conditions it was impossible to undertake anything, and so the troops camped on the ice, only several verstas away from the enemy. Out of the several ships that were wintering in the mouth of the river, two were pulled down for firewood, and the soldiers revived again having warmed a little at camp-fires, which was really a great luxury. That same evening the troops faught..."

The Russians won.

The victory was brought about by the heroism of the soldiers and suddenness of their attack. Barklai-de-Tolli's troops with triumph entered the town, whose walls for the first time in history saw enemy's banners.

For two days the Russian troops covered about 100 verstas over untrodden wastes, in a strong frost, through ice

and deep snow and captured an entire province. The Swedes recognized openly that they were mistaken in their strategic assumptions, considering it utterly impossible to accomplish the crossing of the Kvarken.

The document attracts one's attention not by its stylistic perfection, but by the formative influence it has exerted on the young Berg. It is apparent that Alexander Berg, who copied it for Iohan Berg, and Iohan Berg, who bequested it to his son, and Elizaveta Berg, who treasured it, attached to this paper especial importance, finding it to be of enormous emotional force.

Not the ramshackle banners of the Empire, not the spread two-headed eagle, but the heroic past of the people was the source on which Berg drew beginning his independent life.

Not infrequently, in the hustle and bustle of life we forget about our ancestors, about their deeds, which may be not so outstanding as the Kvarken march, but perhaps are also of no small importance for the generations to come, for them to grow up patriotic, honest and devoted to duty. Sometimes the owner of a dog knows its pedigree better than his own. Too often we ignore our progenitors, although they could help us better to perceive our own selves. After all, good assets do not appear in a man on their own: they may only be developed following their suit.

The First Flutter of the Heart

Reflecting on the early period of Berg's life, one may be led to conclude that he was very lucky. Lucky because his upbringing in his early years was done in a careful and subtle way: father, mother, grandfather and, in a sense, even distant ancestors. He attended good schools, from which he acquired much not only by way of academic knowledge but also by way of moral attitudes. He was also lucky in his adolescence—he was under the influence of a young woman, his friend, a woman whose emotional fineness has left an indelible trace in his life.

... Let us leave the frozen Kvarken, forget for a moment that our hero is going to the war, and go to St. Petersburg. After the icy rocks and the storm of Kvarken we will be engulfed by the warmth and cosiness of the house. Music is resounding, windows are brightly lit. Pairs are dancing

round. Among them our hero. He is in dress garde-marine uniform. He cannot help smiling and is gleaming happily—he holds in his arms a charming blonde with huge grey eyes and plump lips. She is excited and dazzlingly happy. These are bride and bridegroom, Nora Betlingk and Aksel Berg.

Aksel got acquainted with the Betlingk family when he was visiting his relatives. Since 1908 the Betlingks were nearly the only home frequented by our garde-marine.

By the time Mother with sisters were already living at another town, grandfather was becoming so senile that it was impossible to get on with him. True, several times a year all the relatives would come to his place. For a New Year Aksel generally brought him a congratulatory poem in English, German or French—on that day the grandpa got 54 poems, one from each grandchild. By and by the early friendship with the grandfather degenerated into rather formal relations. On the other hand, the Betlingks gained more and more ground in Berg's heart. And gradually it became his home from home. He was attracted by the atmosphere prevailing in that household. Even at home the Betlingks were always busy. Some drew, others improvised. Sometimes Aksel, Nora and her father organized chamber concerts. Nora and her father took turns at the piano, Aksel remained faithful to his Guarneri. The mother was knitting or sewing. Often Betlingk told them stories from his medical practice. Later on, when Berg became a member of the family, he, too, joined the friendly exchange of impressions, related about his sea adventures, about new ships, and his stories invariably aroused a great deal of interest. Although all the members of the family were far from the sea and ships, the scope of their interests was wide.

In winter at Betlingk's once a month there were parties. The youth danced or went in for theatricals, and the seniors, excited by the chaos in the country, discussed politics.

This was a setting favourable for molding a personality, and Berg remained for ever grateful to the Betlingks for the world of emotions they so generously opened for him and into which they admitted him. The atmosphere in the Betlingk family also attracted the boy by the fact that it reminded him of his early years and the warmth of house

of the Bergs, which he had missed so. Here people believed in what he had been taught when a boy, and here was the same atmosphere of understanding and friendship.

"I Burn but Don't Burn Down"

It is hard to say who was the first to attract Aksel's attention, Nora or her father, a major St. Petersburg internist Rudolf Betlingk.

Betlingk was the chief doctor of the insurance company Salamander, the largest in Russia, a fairly well-known company whose motto "I Burn but Don't Burn Down" made it famous, in any case made it a victim of many a columnist. But there was nothing funny in that firm; rather its field was gloomy—insurance of estate and life against fire and other calamities. As far as estate was concerned the insurance practices were age-old, but in life insurance Salamander drew on the latest advances of science.

The company wanted to know the probability of getting some profit when insuring a customer. It was the task of Dr Betlingk to estimate how long a client was going to finance the company in this world, and he made his predictions using mathematical techniques.

His major tool was the theory of probability and statistics, a part of mathematics that lies at the foundation of scientific insurance business and many other fields.

Strange as it might seem, but it was Rudolf Betlingk, a doctor of medicine, who for the first time really unveiled for Berg the beauty and power of the theory of probability and statistics.

"We are colleagues, young man," Betlingk would say to his young friend, "each step of the seaman and the physician is based on probability, do you agree with me?"

But the young man was at first only batting his eyes.

"You see," went on saying that refined gentleman in his Chekhovian pince-nez, elegant and well-groomed, "well, just look: gunfire, navigation, astronomical observations, survey, and finally finding your coordinates at sea—this all is sheer probability. How do you determine, say, the probability of a shell hitting a target? Well, nearly in the same manner as we proceed when we want to determine when the death cuts with the client its scythe. Or rather what is the probability of its deadly weapon hitting a tar-

get? I examine a patient, his health, way of life, study the nature of his professional activities, his character, tastes and predilections. Considering all this, the life of a man can be predicted with a fair accuracy."

Berg began to help the doctor with relish in his quasi-detective investigations. Rummaging through the medical records of patients they both got worked up and argued till they were blue in the face. But unbiased mathematics reconsiled them. How often would Berg remember the doctor in 40 years, when he would conceive a passion for cybernetics, which drew heavily on probability and certain parts of statistics.

The friendship with the doctor would become ever more intimate and would only terminate with the death of Nora's father. The life of that man came tragically to an end at 68 years, and he could hardly foresee that he was going to die a total wrack. Only the affection of the family would save him from an asylum.

But at the time when Berg met him he was a buoyant healthy personality, an enthusiast of skies, tennis, and rowing. He was surrounded by the aura of a veteran of the Russo-Japanese War. He distinguished himself as a field surgeon. At Kuokkala, where the doctor had his summer cottage, he was admired by all the youth, and he was the inspirer of boat races and the organizer of home theatricals, distant excursions and picnics.

Rudolf Betlingk was educated and cultured man. He spoke several languages, was a good reader, knew interesting people—writers, painters, scientists—his clientele was large. So he was the physician to the Maria Opera Theatre, and among his patients and friends were many famous actors and singers of the time. With some of them Berg got acquainted at the doctor's, about others the doctor told him stories.

His home study-room mesmerized Berg. Its walls were entirely covered with book-shelves. And what books were there! Voltaire, Diderot, Rousseau—in the original, the entire Russian classics, many books were with autographs. In the gaps on the walls hung pictures, nearly all of them belonged to the brush of modern painters and most of them were gifts of the authors. On elegant supports were many works of sculpture, most of them produced by the doctor himself, who considered sculpture his hobby. True, at the

time the word wasn't in yet, and so he used another one, calling himself a diletante-sculptor.

From the Betlingks Berg would borrow the rarest books, unavailable at the library of the naval corps, although it enjoyed the reputation of one of the best in St. Petersburg, and returning them to the doctor he would discuss with him all manner of issues, from the rules of the game of tennis to ethic problem of war and service to mankind. They talked much about the meaning of life, the role of arts, the value of self-formation. But literally from the first day of their acquaintance, apart from the common interest, there was an apple of discord, the question of innate superiority of some people over others.

"But, my young friend," the doctor got excited, "after all, you cannot deny the role of inborn powers, heredity?"

The topic keyed the doctor up and his Russian with the accent of a Baltic German became even more funny than ever.

"I can," countered Aksel serenely, "a man can accomplish whatever he desires if he perseveres."

"You are overdoing a bit, *mon cher,* overdoing," the doctor patted Berg's shoulder in a fatherly way, "well, you shouldn't, *du mutest dir zu viel zu, oh!* well take too much upon yourself. Out of a nobody you cannot make a somebody. I assure you. Take our Sasha. We have adopted her, an orphan, from an orphanage. She has been brought up under exactly the same conditions as Nora. We've been teaching her, and what of it? Total dumbness. And who is she actually? Nora's friend? A companion? A maid? I assure you, we love her as our daughter and we spared no expense and effort to educate her. We have been doing our best... But that eternal *Weltschmertz,* or how-d'ye-call-it, world grief..."

In his elastic stride the doctor paced the capacious study-room crammed with rare furniture and antiquities.

"You have been making a poor job of it," it began to get under the garde-marine's skin as well, although neither the voice nor the complection betrayed this, only the eyelids swelled with concentration and his eyes squinted, which was always a sign of his emotional strain, "You haven't developed in her the desire for self-perfection; perhaps you invited the same instructors for her as for Nora, but she maybe had no incentive. What was in stock for her? After

all, she understood that she would never occupy in the society the same position as your daughter. She wasn't confident in her powers, and it was those powers that you failed to strengthen in her..."

"You are overdoing again, believe me, my friend... you... you, so to speak, overcomplicate the potential intellect of Sasha. She is a charming, pretty girl, but she lacks the inherited nobleness, which is inherent in you and Nora."

"But there is no such thing as inherent nobleness, professor, a man is able to develop in himself the required features of character, will-power, courage..."

"It is not always that we achieve whatever we want. Things do happen in life."

If only the poor doctor could know then what bitter prophecy there was in his words!

Already at that time self-perfection was an obsession with the young Berg. His diaries were evidence of this—maxims about duty, honesty, talents. The doctor had never seen those diaries and did not know that the youngster pondered over the issues of self-perfection and self-formation, and he might gather that the garde-marine argued only because at all times the youth did not like to agree with the old age, did not trust it and always wanted to strike new paths in life.

Sometimes some of the guests joined in: the astronomer Glasenap or the doctor's cronies, brothers Struve, also astronomers who came from a family with three generations of astronomers. Some backed the host of the house, others sided with the young mariner.

Dinner time was approaching. Betlingk would glance at his watch from time to time. Now a knock at the door would come—Nora would invite them all to the table.

Nora

It wasn't at first sight that he fell in love with Nora; perhaps three years later. Beyond doubt, she attracted his attention, but he could not yet understand the new feeling, and so it matured gradually in the boy's heart. With the doctor it was all clear. A good solid male friendship with its discussions, its first acquaintance with the life of adults. But with Nora everything was an enigma.

There was no wonder that a first girl that had come his way after years at the cadets and naval corps, where there was not a single woman around (and he had already lost his attachment to his sisters), a first and a pretty one at that, should impress him so. True, Nora impressed not only unfledged youngsters. At Betlingks' there were always many young men and women. The house was frequented by cousins, Nora's companions from the musical school, from the school of fine arts, and young actors of the Maria Opera Theatre. That was an open and hospitable house, and many of the guests came not exactly to see the doctor. They came to see Nora, and some of them offered her not only tickets to theatres and previews, but also their hearts.

Berg could not afford expensive gifts for Nora. But he had other weapons: frankness, determination, and courage, assets so attractive for young girls.

Everything was agreed between them when Berg moved up to the third company of the naval corps. In that year he took two oaths, to country and to bride.

As Aksel "grew into" the Betlingk family, he understood more and more that Nora was a wondrous friend. She was no less interesting than the doctor. Perhaps even more pleasant, because she did not suppress him with her formidable scholarship, rigid attitudes, she herself was searching for her truths. His friendship with Nora was even fuller than with the doctor. Nora not only enriched her friend with her interests, but she eagerly absorbed his discoveries, his revelations.

They together dreamed about their future.

"You will become an admiral," Nora would say, and something in her eyes, some mixture of expectation, command, admiration, and conjuration made him believe in what at other moments would have appeared unrealizable and conceited. But with Nora this all seemed so natural.

"Well, well," agreed Aksel, and the eyes of that girl brought back the sensation he had first experienced in his boyhood in the exhilarating waves of the Baltic Sea.

"And you will became a famous pianist," said he, feeling a desire to conjure up a generous future for her too.

"No, maybe a painter," Nora objected pensively, and some concern was noticeable in her face.

"She is afraid that she'll never recover," supposed Ak-

sel, and he suffered intolerably and groped for some joke that would divert her from her black thoughts, from a misfortune, which at 17 had confined her to bed for long.

"You'll paint sea and ships," he said, "But you don't know a yard from a shroud and think that 'topgallant sail' is the same as 'sale of topgallant things!'.

"I'll learn," laughed Nora, "I'll immediately get round to grinding the maritime vocabulary. By the main mast!"

Nora was a talented person.

She attended simultaneously the Petrischule, a music school and a school of painting, besides she studied several languages and had a good command of them. She just considered that one should know everything and it was absolutely impermissible for something not to be perceived in life. She only felt confident when she found an answer to each of her questions. Life is poor if it has even a tiny white spot. Therefore, she read voraciously, especially about arts, the history of civilization, travels, but, above all, about music—because since her early years she understood that arts and music were going to be the main pursuits all her life.

But it so happened that a chronic cardial disease would often send her to bed and so she could not satisfy her thirst for travels other than through books. She did not loose her heart, she knew that Jules Verne had been to no places and looked at the world only through the walls of his study-room. That had not prevented him, however, from seeing it better than many.

In bed she stuck to the same routine: two hours for languages—English, French, German, four hours for drawing, not less than four hours for reading. And when only she could leave her bed she would run to the piano and played, played, played. Of course, not as before the disease, seven or eight hours, but at least for short whiles, several times a day, defying the doctors, defying rebukes of father and mother. On the days when she expected Aksel, she tried not to play without him to save energy—they generally learned some piece for violin and piano.

But if she only could, she devoted much time to drawing: she drew all and sundry, all those who came to see her. She produced beautiful portraits, which after she had finished the school of arts opened for her the doors to the Academy of Arts, to the class of the well-known portrait-pain-

ter Kardovsky. She also drew what was born by her imagination, and then her products lost their concreteness and became airy and bizarre, and the paints fantastically elusive. In those light strokes and lilac-blue-rose tones was something from Dulac, from his weird and wonderful illustrations to *Arabic Nights,* whose subject interweaved with the subjects of Jules Verne to create the amazing atmosphere of Nora's drawings.

She also dabbled in painting on porcelain. This she learned from Elizaveta Berg, whom she had met when Aksel's mother was living in St. Petersburg. This fine work is only up to an exceedingly neat person, a patient painter with an especial feeling for colour. For paints on porcelain to last the products are burned and this is fraught with specific difficulties. On burning the colours change markedly. And so, when painting the artist must imagine not the initial colour but that, as yet invisible but right, tint. This is art and craft. Elizaveta Berg was a master-craftsman at it, and Nora, too, became fond of it. When the Berg woman left, they communicated via Aksel and directly, by letters; they also exchanged their products. Little has survived of Nora's works but one miniature, the portrait of a child on porcelain had remained with Aksel for life. It is hard to imagine how he managed to carry that fragile piece through his long and tempestuous life. More than half a century that souvenir had been with him.

In those days Nora was reading much poetry. Since the helter-skelter of everyday life did not devour so much time, she rediscovered for herself Heine and Goethe, she read in raptures *Die Harzreise, Manfred, Don Juan* and was struck by the magnetism and fanciful, tempting heroes not to be encountered in everyday life. And Rostand with his *Princesse lointaine...* They would carry her away to the world of dreams, of romanticism. In Nora's soul burgeoned some special sensation of beauty and fascination, some reverence for the powers of human fantasy, which from a chaos of surrounding sounds and colours compose the marvelous fairy-tale of music, poetry and painting.

And when Aksel came they had no enough time to relate to each other their fresh discoveries during the several days. Nora not only confided in him what she had learned and what she speculated on, not only defended her new favourites, German poets, from Aksel's disgust (courtesy von

Bursi), but also attended to him with eager curiosity: he was a denizen of another world, real and exciting, whose personages were sea, mysterious schooners, dreadnaughts, battleships and cruisers; she made heroic attempts to distinguish them, at least in pictures. Weather and her health permitting, she went with Aksel to the Naval Museum where he introduced her to the world to which he completely devoted 18 years of his life. They would for hours stay in the port, which was alive with international shipping, and Nora was enriching her maritime education with great pleasure. She could not swim, however, and dreaded water awfully. But mastering her fear, she went out with Aksel in a yacht into the gulf. And when her fearless helmsman, still without riffing in a good breeze, nearly put the yacht on its side, Nora grew white with horror and her eyes became round like a bird's. She didn't complain, however, and was stoically preparing herself for the role of a naval wife.

The declaration of love took place in the fourth year of their acquaintance, near the Krestovsky Island, after one of those yachting expeditions. The galant seaman wanted to have the yacht as a place for that momentous event, but thought better of it: on the yacht Nora would hardly be fit to follow him. On the yacht she was exclusively interested in one question: whether or not she was going to drown this time. And so the place was not that romantic, although more safe—in a horse-driven cart en route home.

Nora announced her decision to the Betlingks, Aksel wrote to mother and sisters. The parents were much less surprised than the lovers themselves—everybody seemed to have expected this for a long time. The children were blessed. Nora and Aksel became bride and bridegroom.

I look at the photograph of Nora, and I understand the choice of Berg. Perhaps, Nora cannot be called a beauty, but her face is bound to attract one's attention and arouse interest. This was the face of a thinking person, the face of an intelligent, charming woman. The eyes, penetrating into your soul, they suggest a subtle, impressionable, emotionally-laiden nature. She looks at you from the photograph the way people rarely look into the objective-lens; through the camera, directly into the soul of the beholder, into the future. And she foreboded her fate, this is obvious in all her photographs—here she put down her

knitting on her lap and raised her oval mild face in the fuzzy aura of hair, the corners of her lips a bit down, the mouth of a hurt child; here she is in a summer frock, maybe on a yacht, the wind plays with her hair, she is full of sun, but not joy. The head is thrown back a bit, she seems to listen to something—perhaps she makes out the first alarming sounds? This is the spring of 1915, the husband puts out to sea.

A War Time Wedding

During the early period of war Berg served as a junior navigator on *Tsesarevich*. This hurt him. Hurt because his circumnavigation went by the board, hurt that he got on the *Tsesarevich,* an old tub, a veteran of the Russo-Japanese War. When the Japanese unexpectedly attacked the Russian squadron at Port Arthur the *Tsesarevich* got a torpedo. After the war the ship was sent over to the Baltic Sea, and by the time Berg was commissioned to it the veteran had had behind its belt many years of service. Happily, the ship escaped the early stubborn battles, they might well be his last exploits.

Berg was so eager to get on one of the modern vessels, by the time there appeared ships of dreadnaught type, beautiful things with 12-inch cannons. And several of them had already been members of the Baltic Fleet. Some of them would cover themselves with glory, and under new names—*Marat, Oktober Revolution*—would serve for years in the Soviet navy.

In the spring of 1915 the *Tsesarevich* and other large ships departed for the Aland skerries, the same skerries that had been thoroughly explored by the young navigator of the *Tsesarevich* back in his boyhood days. Here a watchful war of nerves was under way. The Germans tried to get into the Gulf of Finland, and together with other ships *Tsesarevich* was called upon to prevent them from doing it. On one of the rocky islands 14-inch guns were installed. They covered the sorties and skirmishes of the Russian craft.

Out of the skerries the ships put out to sea and blocked the way to St. Petersburg, or Petrograd as the Russian capital came to be called since the beginning of the war with the Germans. In one of the operations the *Tsesarevich* was damaged again.

In winter the war on the sea waned and ships were repaired. During the winter lull some of the officers even could go on vocations and returned to their homes, to nearly peace-time life.

And strange as it may seem, in that troubled time there were many weddings. Such was the ironic logic of events. Wars have a number of unavoidable consequences. Some die in a war, and survivors are in a hurry to marry. During a war the birth rate is low; and after the war, babies come in greater numbers than in normal times.

If viewed through the eyes of our hero, World War I was rich in events. In the end of 1914, when Berg served on *Tsesarevich,* died Antonio Bertoldi at 89. The fleet laid idle in Helsingfors and Revel, and Aksel was allowed to go for several days to Petrograd to pay the last tribute to his grandfather. During those few days he managed not only to appear at the grandfather's graveside but also to marry.

Just imagine a young officer on board a warship during a quiet spell. Ahead lied total uncertainty, quite likely death, or injury, or hospital. Those who had families tried to go on leave and to spend it with their families. Others went on a razzle-dazzle. Berg was 21 when in the winter of 1914 he arrived in Petrograd. Here his bride waited for him. Of course, the young people did not want to take risks. They made arrangements with their parents and the wedding took place. It proceeded according to the rules of the Lutheran rite in Petrikirche, St. Peter and Paul in Nevsky Prospect. A wedding in a Lutheran church is less pompous than in other churches, but it is warmer and more solemn. The Pastor pronounced what suited the occasion. But that was not an abstract speech, but rather injunctions for Nora and Aksel. When at the Alexander Cadets Corps Aksel went to this church with his family each Sunday. This church was also attended by the ten or dozen Lutheran families from the neighbourhood, including the Betlingk family. Therefore, the wedding ceremony was an almost family affair. The Pastor and all the parishers knew the young people and had sympathy with them. A war-time situation, the uncertainty of the future, the age of the young couple, this all imparted to the wedding an unusual aspect. After the wedding the young couple was brought to the railway terminal, put on a train and sent off to Helsingfors.

Neither of them had lived in hotels before. The several days of the leave flew by like an hour. Aksel returned to the ship. Nora remained alone. It seemed absurd to leave one's family behind to go to a strange town just to live there alone, without husband. She could hardly walk. With her heart any disease could lead to a complication, and at all times she had to be accompanied with somebody. But she was anxious to be near Aksel, neglecting comforts and risking her health.

By degrees life was settling down. The Betlingks came to Helsingfors and brought Sasha, they rented a flat for the newlyweds. At the time Helsingfors was already a civilized and agreeable town. The Bergs now lived in a cosy flat with four rooms in a new house. The house was equipped with a special-purpose fire-wood lift, a rare luxury at the time. Nora plunged into her house-wifely duties and cheered up gradually. Her companion was Sasha, who remained with Nora for life, from their early years to the end, when both of them starved to death in 1943 in besieged Leningrad.

The winters of 1915 and 1916 the *Tsesarevich* was birthed at Helsingfors, and so Berg could spend his evenings at home. It was almost peace-time life, and the chaos of the first days of their union worked out to happiness. Nora even joined a school of drawing and music. The newly married couple had a very narrow acquaintance and, waiting for her husband, Nora mostly played and drew. And she felt in those war winters much better. The only heavy period was the spring and summer of 1915 when the *Tsesarevich* went for a long cruise and not until late autumn was Nora aware of whether or not her husband was alive.

Chapter Five

A Fight with Deviation

Signs of Future Pursuits

In the anxious life of Berg appeared a novel element. He plunged into scientific work. That bordered on the impossible—war, hostilities, duties, responsibilities. He, the junior navigator, the second navigator Frankovsky and their chief Captain Ogilvi had always to be on the alert, always ready to shape the course of the ship. They had hard time in skerries, with their involved canals, among mines, both Russian and German, in dense Baltic fogs.

Berg explained: "If a navigator could not find the location of his ship the chances of the crew to return home were nil. In the First World War many ships and submarines were sunk on mine fields.

"How many mines were there in the Baltic Sea? Several tens of thousands, for sure. We knew, more or less exactly the locations of our mine fields, from the disasters with our ships we got some clues as to the arrangements of German fields and so we did our best to stick to save regions, that is, ones in which navigated German warships and mostly submarines. We tried to steal along in their wake. But those locations and courses had to be found and followed with extreme accuracy. And to this end, a navigator must know exactly his position on the sea, at any time of the day, in any weather.

"Easier said than done! This was one hell of a problem, especially with shores unseen, after many days at sea when all the devices got out of hand, with nothing to check them with.

"To be sure, compasses were of some help, and in the fog or by night they were the last resorts, but these very compasses at the same time made the life of navigators harder. The paradox comes from the structural material of a modern ship. Ships are mostly made of steel and magnetic compasses in the presence of such a mass of magnetic

metal are erroneous. On a ship a magnetic compass may be in err up to 3 points. Things are complicated even more by the fact that the error is not constant but varies with time, depending on the way in which the steel masses of the ship are magnetized, on the course of the ship, and on the number and arrangement of electric appliances in operation on the ship, which sometimes total several hundred. The error even changes on turning the cannons. How can one possibly take one's bearings under such circumstances? How can one master the deviation—the deflection of the hand of magnetic compasses from the true north?

Investigation into the deviation and control of the deviation became the main occupation of the junior navigator of the battleship *Tsesarevich* Aksel Berg.

Berg got interested in that problem as early as 1911, in the junior garde-marine class, when they got started on the course in deviation theory. In winter, garde-marines studied the theory, and in summer, on their training cruises, they were mastering the practical aspects of the problem. Since the correct account of the magnetic field of a ship is bread and butter of the navigator profession, in the naval corps that course was regarded as one of the main subjects and lasted three years. The theory of navigation was read by the foremost expert of the time Pavlinov, who based his course on a solid physical and mathematical foundation. The classes were conducted in a beautifully outfitted room of magnetic compasses, so that the graduates of the corps were quite well equipped to combat the treachery of the magnetic needle. Garde-marine Berg even in his corps days was not content with the obligatory literature prescribed by the curriculum, he dug and delved for additional literature and read any book on the subject that came his way. This enabled him not only to absorb all that had been achieved in this domain but also to reach the frontiers and to come to grips with them. Of especial help for him was the book by Ogloblinsky on deviation. The contents of the book surpassed by far what was necessary for a garde-marine. But Berg drew on it repeatedly. The intensive studies turned out to be of much help when he had to handle deviation practically on a warship. After all, the degree of competence of a navigator was crucial for his own life, the life of the crew and the ship.

Berg not only took due account of the deviation of the

magnetic compasses on the *Tsesarevich* at the highest scientific level possible, that is, with a minimal error, but during several years he kept gleaning and statistically processing deviation measurements under all manner of circumstances. This work started a whole series of works on navigation carried out by Berg on submarines at a later date, and the graphs alone, or, to use the parlance of science, curves, amounted with time to thick albums.

After *Tsesarevich,* an object of Berg's attention became the compasses of the British submarine E-8, to which he was transferred in 1916. During the First World War it was agreed that Russian navigating officers would be assigned to the Allied submarines operating in the Baltic.

At the time fresh in the memory of the navies was the fate of a British sub that was making for the Baltic Sea. On leaving Britain the submarine, because of the incorrect account of the deviation of its compasses, in the fog missed the entrance to the Straits of Denmark and at low water appeared to be exposed on a shallow near the Danish shores. The situation was hopeless, before the next high water period the sub could not become afloat, and so it lay helpless and exposed in clear sight of the shore batteries of the enemy. The Germans shelled it at leasure.

Berg's experience of independent work was still insignificant, and here he had to live with new colleagues, the British, representatives of a nation that once ruled the waves and whose seafaring reputation was exceedingly high. In addition, he was confronted with a yet harder nut to crack, yet more insidious enemy—deviation on a submarine.

Its accurate account is complicated beyond belief. To reduce deviation on surface ships, magnetic compasses are placed on the bridge, high above the bulk of the magnetic masses of the hull. On a submarine, only the main compass is located on the bridge, the remaining devices are nilly-willy installed within the bowels of the ship. But the main compass is only accessible when the submarine is surfaced. What is more, to take its reading, a navigator must each time leave the central control compartment, climb up, and, if the sea is rough, to reach the compass assailed by high seas. When submerged, that compass is of course of no use. The one inside is utilized instead. But this device is surrounded by masses of iron. Furthermore, a submerged submarine is powered by d.c. electric motors,

which depending on speed draw up to 5000 amperes. By way of comparison, auxiliary motors on battleships draw a current of hundreds of amperes, and they are normally supplied with alternating current, which exerts lesser influence on the magnetic needle. Therefore, magnetic fields produced by motors and wiring on a submarine are tens and hundreds times higher than on surface ships. Especial nuisance is the dependence of those fields on the working conditions of the motors. The higher the power they develop, the higher the magnetic fields, and hence the higher the deviation of the sub's compasses.

Not to be lost under these conditions on a submerged submarine takes a wizard of a navigator who, having cast a casual glance at the needle of a compass gone crazy and appealing for help to the Creator or the Satan, with just unreliable assistance of special-purpose tables, would supply to the captain the location and course of the ship.

Later on gyroscopic compasses made their appearance, and magnetic ones were only left as emergency stand-bys, but at that time there were no sign of them, and so the young navigator, having arrived at the E-8, recommenced his activities from scratch, he set out to explore the deviation of magnetic compasses, but now under the conditions of a submarine.

The first plots shocked Berg, he had not expected the picture to be all that chearless. On the E-18 the deviations not only had not been removed, they had not even been estimated within reasonable accuracy. This was made clear to Berg in the first cruise. He found out that the British navigating officer Smith drafted from reserve had long forgotten what he had been taught in his time. The Russian navigator Pavlov, Berg's immediate predecessor, seemed to have been quite a lax character, the junior navigator Berridge was an incompetent and happy-go-lucky sort of person. He just did not care for such an irksome thing as deviation.

Helped by three Russian ratings assigned together with him to the task, he rolled up the sleeves. He took due note of and compensated for the deviation of all the compasses available, and then was keeping a watchful eye on fresh errors, and when they exceeded permissible values, he removed them again.

To this end, he required that between operations the sub-

marine was brought out to sea and run for hours with different courses and speeds both surfaced and submerged in view of light-houses. Indefatigably, he was comparing the readings of the compasses with true courses. At first the differences were shattering. The navigator carefully removed the errors using special small magnets, and again directed the sub on this course for control.

The crew, unaware of the true reasons for those added labours, grumbled and cursed the whims of the Russian. Some of the officers, stirred up by Berridge, were ridiculing the pedantry of the new navigator, reproached him with hair-splitting and considered him a pain in the neck. Berg tried to humour them and carried on with his business.

"Mister Tomorrow" and History

The atmosphere at the Allied submarine turned out for the Russians to be far from simple.

The Englishmen always remembered that their country was a great sea power, and some of them were rather arrogant. They used to discuss the Russian ways with derision, although not always without good reason.

The Russian navy was commissioning modern ships, but its Achilles' heel was logistics. Russian submarines splendidly designed by the prominent scientist and designer I. Bubnov were essentially unfit for action. Instead of 1320 h.p. diesels as designed, which just before the war had been ordered in Germany and Sweden and of course could not be had, they were equipped with rediculously small diesels, only 200 h.p., recovered from the gun-boats of the Amur flotilla. Those submarines progressed at a snail's pace.

The Russian officers and men boiled with indignation and critisized the government. The Englishmen called the officials of the Revel naval dockyard "Mister Tomorrow": quartermasters lavished promises but did not supply in time fuel, provisions, materiel. The most popular answer was "tomorrow".

Berg grasped the situation at once—the Englishmen felt absolutely at ease, since they got used to the company of Russians who did not understand English. When Berg was commissioned to an English submarine, he ordered a his-

tory of Britain in several volumes and was burning midnight oil cramming it up. You may well ask, why history at a time like that? The deviation is formidable, operations follow one after another and in some of them the sub is on the brink of a fatality; Mr Berridge, instead of mastering navigation, only cares for Revel girls, and here we have a Russian navigator taking British history!

Only few knew of that pastime of Berg's though. That was his small mystery. Before long it turned out, however, that those history studies acted as a cement to strengthen discipline on the submarine, and quite unexpectedly gained prestige for the young navigator.

The Britishers had only to open their mouths riding their favourite hobby of running down Russian ways, Berg was there with a yet more picturesque example from the history of the British Empire. And since most of them were not terribly good at history, Berg's example would quickly take them down a peg or two. Gradually, the indiscriminate censure of all things Russian and sceptical talk abated. Russia and the Russians stopped to be an Aunt Sally.

At the time the situation in Russia was tragic and by no means ridiculous.

The February Revolution broke out. The Provisional Government, like the Czarist government before, could not explain to the people the ends pursued in the war. Soldiers were tired of the senseless slaughter, and gradually, owing to the activities of the Bolsheviks, were beginning to understand its true character. They declined to fight for the interests of the propertied classes, for the profits of English and French colonialists.

The front was coming into a state of disarrangement, but the navy was still fighting, otherwise the Germans would have taken Petrograd. As early as the late September of 1917 the German navy, taking advantage of the laissez-faire of the English and French navies, broke through the defence line of the islands Ezel, Dago, Moon, and Vorms. The Germans were seeking to strike at Petrograd. But they were driven out of the Gulf of Finland. The navy was with the Bolsheviks and defended Petrograd. The Second Congress of Baltic navy men decidedly came out for the transfer of power to the Soviets. The Provisional Government was living its last days.

Lost in those political tempests, some czarist officers committed suicide, others emigrated. The most patriotic members of the Russian officerdom sided with the eminent revolution. The English were haywire, they called some fools, others traitors.

The crew of the E-8 was really acquainted with their "own Russians", the officer and three ratings, and treated them with respect. The English submariners understood that the young Russian navigator is a man's man, no "mister tomorrow", no fool, no traitor.

When in the winter of 1916-17 Berg went to Helsingfors to attend the officers' navigation class, the English got worried: would he come back? After the abdication of the czar, E-8 continued to be a member of the Russian navy. The captain was greatly interested in retaining an efficient crew and hoped to have their navigator back on the submarine.

They applied to the Soviet of Sailors' Deputies elected by the Russian sailors who served at the submarine base and the Russian sailors, members of the English crews with Russian navigators on eight English submarines. The Soviet sent a representative to Helsingfors, who found Berg there and told him that the Soviet supported the plea of the English crew and required that he continued his service on the E-8.

Berg obeyed the order of the Soviet and throughout the campaign of 1917, E-8 was sailing with her old navigator.

An Encounter with Radio

These years were very eventful for Berg. His relations with Nora were taking on a strange aspect. Their married life started during World War I, and they lived through two revolutions and civil war. The first three winters in Helsingfors were quiet and nearly peaceful—during the first and second winters the *Tsesarevich* was being repaired in Helsingfors and the officers in the evening returned to their families; in the third winter, in 1916-17, between two campaigns on the E-8 Berg was attending the Helsingfors navigation classes and again he was with Nora. But during summers he went to war and Nora was having not the faintest idea of whether he was alive, what ports the submarine would call for supplies and where she might see him even for a moment. Nora, like other naval wives, got no

messages, and so they constantly awaited the worst outcome. They haunted the port and witnessed many a tragedy. Nora had been in the grips of perpetual, tantalizing anxiety. And her fears were not without ground. Tragedies occurred first in one and then in another of the families of her acquaintances. Once Nora was waiting for Berg together with the wife of a young officer, Essen, son of Admiral Essen and Aksel's friend. The submarine *Bars,* with Essen junior on board, was lost. And Nora had spent many days with the sorrowful young widow, helping her in her torments and dreading her own fate. All the wives went through similar nervous strains, because from time to time a ship did not return home. This sort of life was telling sadly on her delicate health and gave rise to a series of heart attacks.

But what was in store for her and other officers' wives in those tragic days?

Each ship of war was a partner to the dangerous play of cat and mouse with the sea and the enemy, and for submarines the situation was even harder.

A submarine was brought into general quarters immediately on being brought under way. Its total isolation started with the moment it left the port. At the time it could become a victim both to hostile and friendly ships, and so it had to be committed to double concealment. It had to get through all the hindrances engineered by the enemy or against the enemy, such as mine fields, net barrages, to sneak along undetected by aircraft and patrol ships, which in those days were yet unable to identify a submarine. And so any stir or fuel spot might be shelled. No time for identification, a second decided all: while a submarine was being identified, it might dive and send out its deadly torpedoes. The law of war is cruel and logical: attack or be attacked. Manoeuvre, hide, be able to disappear like a fish.

And in that strenuous state a submarine was from its departure up to the very moment it had passed through harbour boom of its home base. It had not to expose itself even a moment earlier, otherwise it might be shelled by Russian shore batteries.

"Take the happiest moment, the moment of arrival after a week's cruise," explained Berg, "a submarine is coming in. You perhaps imagine that it makes its appearance under the accompaniment of joyful splashes of the sea, the crew

rushes out on deck. Everybody are embracing each other and shriek 'For the czar, for the country!'. Nothing of the sort. This moment is nearly the most dangerous one. And the crew have no idea about it. The whereabouts of the submarine are only known to the captain and the navigator. The captain takes a decision concerning any function of the submarine. Only he or the mate looks into the periscope and see the shore or enemy, clear sea or ships on the horizon. And the crew are blindly carrying out their orders. The crew of a submarine are doing their routine work in a routine situation, suspecting nothing about the goings-on on the surface. Precisely as during exercises in peacetimes. Therefore, there is actually no possibility for heroic behaviour other than just to attend conscientiously to one's duties, despite all the stuffiness, and sometimes explosions of depth charges. No hubble-bubble, no fuss, all the commands are executed quickly and silently. And then—either you explode, or not; either you die, or remain alive. I was furious with the arrangement. I was raking my head over a problem that at the time seemed insurmountable. How to make it possible for a submarine to communicate with the outside world? How to distinguish a hostile submarine from a friendly one? How to prevent a horrible mistake, which early in 1917 led to the loss of a Russian submarine, sunk by a Russian ship? And that was not by any means a single instance. The same thing occurred in 1914 with the Germans, when the sub U-96 sank U-7."

These speculations brought Berg into a field of science that became for him his main endeavour throughout the rest of his life—radio engineering.

Radio was born at about the same year as Berg. The decisive experiments of Popov and Marconi became known in 1895.

Berg was a child when Popov at a meeting of the Russian Physical and Chemical Society delivered his famous report about the potentialities of using the electromagnetic waves discovered by Henrich Herz for communications.

Men of science could then really perceive the enigmatic Maxwell's equations, which had been beyond many. Herz proved that in nature there exist electromagnetic waves permeating the universe and travelling through stellar worlds with the highest speed possible, the speed of light. Popov made one step further, he, together with Marconi,

proved their practical value. Popov pioneered the use of radio communications in the navy.

The era of radio came in. Herz and Popov, Brown and Rutherford, Tesla and Marconi were the pioneers. In their wake came an army of radiomen. Communication of signals without wire and paper over large distances, over seas and mountains, the sensation of the 20th century, became commonplace now.

Practical men were seeking ways of producing powerful radiowaves capable of covering large distances. That was what occupied the mind of Berg when the young navigator was off duty, he was looking forward to the whole navy having a reliable radio, especially submarines. Wireless could reach an airplane far from its air field, and a ship in the open sea. It could inform those concerned that it is a friendly submarine, not enemy, that is approaching a port. But radio was still in its infancy, nothing ready-made was available, much had to be started from scratch, and the young officer of the Russian navy had neither knowledge, nor equipment, nor time. Above all, no experience. True, some rudiments of that knowledge he had acquired even in the naval corps. Radio was taught by the minor Lieutenant Shanyavsky. (At the time in the navy radio was still considered the domain of mine officers.) He organized a small radiotechnical laboratory on the stair-case of the main entrance. It was equipped with marine radio-telegraph spark stations and primitive receivers. That was about all.

Neither the students nor Shanyavsky himself understood the theory. They just followed the instructions: switch on, turn, press... No inkling of the why's. Curriculum allotted only several hours for radio classes, and of course they could not give even a smattering of the subject and aroused no interest in radio and radio engineering.

Only in 1907 appeared a book on radio-telegraphy by A. Petrovsky. In 1916 a textbook by L. Muravyov was published under the title *A Course of the Class of Telegraph Unter-offizier*. This was a practical book, it described real radio stations. The early books on radio engineering were best-sellers.

It took a major war for everybody to become interested in radios. The enigmatic powers of the wireless became especially conspicuous after the unexpected wreck of the

German cruiser *Magdeburg*. The reports about it were largely responsible for the fact that radio overnight became the talk of the town and the hero of wild legends. But the *Magdeburg* story was really impressive and turned out to have thousands of "eye witnesses". In late August of 1914 the *Magdeburg* was sent out to collect intelligence and lay mine fields in the Gulf of Finland. By night, in pitch darkness and thick fog, owing to a navigational mistake, *Magdeburg* hit the ground near a small island at the entrance to the Gulf of Finland. This was an absolutely flat, low sand island without a single tree or a bush. It was next to impossible to detect it in the night, with all the lights out. The light-house, of course, was out too, and so was the radio-telegraph station.

Having seen, much to their surprise, that a powerful cruiser with its huge hull slid into the islet, the personnel of the station immediately sent a signal to this effect to the chief of naval operations. An emergency. Berg recalls that they were on duty round the clock and listened to the wireless informing them about the situation on the scene. It was like a show—with everybody watching. The light-house was sending out radiograms no end, the *Magdeburg* and German relieve destroyers were radioing too, and messages from the head-quarters showered in. The blizzard on the air, with all the world listening in. It was then that the world understood that from a distance of several hundreds of miles one can follow the developments on the scene.

For a long time since then the Germans were afraid to poke their noses from their Baltic ports.

A first-class German cruiser was destroyed, the mining of the Gulf of Finland was hindered, but that event had some more serious implications. During the panic, when some of the crew had already been removed from the ship by a German destroyer, the Germans threw overboard operational codes. They did not take into account that the place was relatively shallow, and besides they had no time to remove them. And so the codes got into the Russian hands absolutely intact. This cost the Germans dearly: throughout the war Russian head-quarters were breaking the codes of all the German radio messages despite the fact that the keys and codes were changed repeatedly.

Now every naval officer was encouraged to study decod-

ing. Radio operators were intercepting heaps of messages, and officers took turns breaking them. So they spent much time in radio rooms and watched in fascination the work of radio operators, some of whom were aces of their art.

Officers studied coding techniques and were good at it, but about radio equipment their notion was quite superficial. Even more so about the theory.

Once in the summer of 1916 Berg observed in amazement how a strange submarine intermittently dived and surfaced. She was fitted with some incongruous metal structure on the bow. Much later he found out that Ivan Rengarten, the flag radiotelegraphist of the Baltic Fleet, and Nikolai Papaleksi, later Academician and then a young physicist, had been conducting on the submarine *Tigr* the first experiments on underwater radio communications. They had tried to adjust aerials for transmission and reception of radiowaves under water.

"Those experiments, which occurred in view of the entire squadron, were vividly discussed on the ships", recollected Berg, "we, of course understood but little of what exactly was taking place and what was the difficulty, but we got to know that those trials produced positive results and for the first time enabled underwater radio communication to be achieved on our submarines."

Berg went on to relate: "Ivan Rengarten was a remarkable personality in the navy, one of those officers with progressive views who at once sided with the proletarian revolution. Rengarten had devoted many years to the experimental studies of submarine radio communications and carried on his work under the Soviet power as well, but unfortunately he died early of typhus."

Although more than 70 years have passed since Rengarten's experiments, some questions in underwater radio communication still remain unanswered. Up until now reception at large depths is difficult, although modern electronics has powerful and sophisticated means. The fact is that, while propagating easily through the air, radiowaves cannot penetrate deep under the sea surface. In submarine radiocommunication long aerials are used as before, because this communication is normally performed on very long waves.

Witnessing Rengarten's experiments Berg did not suspect that there existed all those difficulties, he was then car-

ried away by the very idea of underwater detection of radiowaves. And he decided to pursue that idea.

In his disposal were only *Scientific Foundations of Wireless Telegraphy* by Petrovsky, a low-power transmitter and a primitive crystal receiver. The E-8 was equipped with a telescopic mast, but it could only be raised 5 metres. Under those conditions reception borders on art. The art consisted in finding on the crystal a sensitive point that looked exactly like all others on the crystal's surface. Radiotelegraphist Efremov, one of the Russian sailors serving with Berg on the E-8 was a master of that art and taught the young navigator. During the reception hour both of them were busy with the receiver, but quite often exactly at the right moment contact was disturbed, radio communication stopped and they sweated again to restore it.

Good Luck or Art?

Having learned to handle the radioequipment of the E-8 Berg did more than just provide contact with the world. It turned out that radio could also come of help in another, no less important and difficult business: to find the exact location of the submarine. Although at sea a navigator is helped besides the compass by stars, they often appear unreliable. When shores are out of sight, the navigator may resort to astronomical observations and, after rather simple calculations, fix his position. To this end, he would have to be able to measure the elevation of some star and to know precisely the time. The first task is solved using a device called the sextant. Berg was very good at astronavigation and liked it, because since his early years he was fond of astronomy, and those measurements were child's play for him. But what about the exact time? On ships it is found using a chronometer. But with unstable temperature, pressure and humidity, under rolling and pitching, the best chronometers are far from ideal. Errors amount to fractions of a second and even seconds a day. In long cruises errors accumulate. Ideally, the pace of a chronometer is checked daily and appropriate corrections are introduced into calculations, otherwise the position error may be as high as several miles.

Radio came to help. At the time some stations started sending out time radiosignals: in Paris on the Eiffel To-

wer; in Germany, at Norddeich, Nauen and Eilwese. They were miraculously powerful for the time—up to 20 kilowatt. The time signals were, of course, meant for the ships of the nation, but everybody who could catch them was free to use them. Signals were beamed out at midnight on very long waves. Berg and Efremov started a hunt for those signals. That was quite a job!

The aerial and receiver available on the E-8 only enabled the signal to be received in the surface condition, with the aerial raised. But when a submarine surfaces, she generally switches on her diesels to charge her batteries. On the surface the sub was rocked, the low-profile aerial would intermittently dive, and the reception was a capricious thing—it was necessary to look for that damned point. When Berg and Efremov were making their preparations for the night sorcery the submarine literally gasped, everything was silenced, even the diesels for a time were cut out—Berg and Efremov are tuning to Paris, their success was of vital importance for the ship.

But the submarine not just became quiet. Like any beast that plays dead in emergency, all the senses were especially keen. Each second it was ready to show "fangs" and "claws" or take refuge under the water. And German patrol ships, mine sweepers, destroyers and flying boats were hunting submarines at night, when they used to surface for charging and ventilation, and exactly in those regions where there were no mines. And so two or three hours on the surface, often in a weather were nerverending for the crew. Often the submarine had to dive immediately, thus bending the mast and breaking the aerial. It goes without saying, that the two enthusiasts had no time to dismantle them. Next night, instead of reception, Berg and Efremov crawled over the deck with pliers and hammers frantically restoring their fragile gear.

Papaleksi and Rengarten had found an answer. They recommended to install on Russian submarines stationary frame-type radionets. Berg was quick to follow this recommendation. And now the submarine was able to receive time signals without raising the telescopic mast. However, new problems emerged. The reception became poorer and more difficult. It called for huge art and experience to catch weak call-signs of Paris or Nauen drawned by noise.

But radio engineering was making its strides. Now, in-

stead of crystals, it could offer gas-filled glass bulbs. They had a forbidding name—heterodine—and glew with their eerie bluish light. The heterodine only received radiosignals when the operator set the right regime, that is, selected the right voltage and current through the valves. Otherwise the valves were stubbornly dumb. In the language of the instructions it was described as follows: to achieve operation in the most sensitive regime it is necessary to find an inflection on the broken anode characteristics of the gas-filled valves. But that inflection—the working point of the valve—kept wondering for some reason. And, unlike the crystal, hitting the working point required not just a piece of luck but long arduous systematic measurements.

For Berg and Efremov, after the long hours of exercises with the crystal, this was just a piece of cake. Efremov was manipulating the valve and Berg was listening in his earphones, catching a signal to check the chronometer. They were 23 each, they had guts and character, and perhaps a bit of luck. At any rate, the E-8 had long managed to slide unharmed among mine fields.

Berg laughed: "I'm grateful to the Germans for the good work of the Nauen station and to the French for their broadcasts from the Eiffel Tower. They helped me to survive and to become imbued with respect for radio engineering."

For the 1917 navigation Berg was preparing more thoroughly. While studying at the Helsingfors navigation classes in the winter of 1916-17 he got a better understanding of radio, he studied the theory and mastered the latest equipment.

If Berg could be said to have been lucky, then he was especially lucky in meetings. At the classes radio was taught by Menshikov, the author of one of the first textbooks on radio engineering. An enthusiast of radio, he organized a radiotelegraphy class, which was excellently outfitted for the time. Menshikov was able to infect the audience with his enthusiasm. A sizable portion of that enthusiasm rubbed off on Berg. At the time you could not find a better radio school. And so Berg received a good sound grounding. Now he could confidently receive time signals in the open sea, even in a fresh weather, with the sub half-submerged, with the mast down, just using an isolated frame aerial. That was a first-class performance for 1917.

From the Compass to the Radio Direction-Finder

For Berg E-8 was not only a school of practical radio operation, but also a magnetic laboratory, where, as we know, he continued his deviation studies. It was only natural that here his new fascination with radio merged with his old hobby of deviation fighting.

With more experience he could now make a step further. It turned out that the frame aerial, which is essentially a rectangular or circular structure with some copper wire wound on it, possessed a wondrous property. It could feel the direction at a radio transmitter. When the frame's plane was perpendicular to the direction at the transmitter, the reception was at minimum, and when it was aligned with it, at maximum. Thus, by rotating the control and observing the reception intensity, it was possible to find the direction from which the waves were arriving, that is, the direction of the radio station.

This showed a complete analogy with the magnetic needle. But if the magnetic needle points at the north, "the radio needle", at a shore radiostation. It goes without saying, that Berg did not lose the opportunity to make use of that makeshift radio direction-finder.

True, the isolated frame aerial on the E-8 was dead fixed, and it could only be turned by turning the sub itself. It can be easily imagined how arduous and time-consuming that procedure was. But wanting to check the reading of the magnetic compass the captain at every suitable opportunity permitted the navigator to take his radio bearings.

And Berg, having found the directions for two known references—north and a shore station—after some fairly simple trigonometry, supplied accurate coordinates of the submarine.

It seemed that the ideal had been reached. But Berg was not satisfied. It is well known that any achievement gives rise to new requirements, and hence new problems.

What made Berg and other navigators who now had direction-finder at their disposal unhappy? The point was that the remarkable properties of the direction-finder only show up "in the clear field". The ship is a source of distortions. The metal hull and other metal masses are as harmful for the direction-finder as they are for the compass.

A navigator reasoned along the following lines. Quite naturally, the metal components surrounding the direction-finder play the role of a shield for the arriving radiowaves. The metal reflects them, just as a mirror reflects light. And some of the reflected waves strike the aerial of the direction-finder mounted above the metal hull of the ship. And so the direction-finder receives not only the signal from the transmitter but also the reflected signals. This extraneous wave is the cause of the errors. It "confuses" the device making it give erroneous indications.

So Berg encountered a kind of radio deviation, akin to his old enemy, magnetic deviation, he had been fighting so stubbornly.

Berg performed a mathematical analysis of the interaction of the frame aerial and the hull with the incident radiowave and yielded quantitative estimates of errors involved. He found that there was a systematic error due to the asymmetric arrangement of the aerial relative to the iron masses of the ship, and that it could be removed by correctly placing the aerial. Other errors were found to depend on the position of the aerial relative to the hull, on the wavelength of the transmitting station, and so on. Berg indicated way to diminish them.

Of especial importance for navigators used to dealing with magnetic compasses was the correlation, found by Berg, between the direction-finder and magnetic errors. Berg used these findings to develop a theory and computational techniques in the form suitable for the practitioners.

Berg subjected his magnetic and direction-finder observations to a more rigorous mathematical treatment later, when he served on the destroyer *Captain Belli* and the submarine *Pantera*. At that time he had been already attending lectures at the Politechnical Institute and Petrograd University and acquired a solid knowledge of higher mathematics. He even started writing a book in which the critical review of earlier work and his own conclusions were based on the extensive experience and good theory. But the book was not finished. The manuscript with the source material perished together with the submarine base *Azov Memory*. To restore the deviation curves plotted at the *Tsesarevich* and E-8 was impossible. Berg would never return to magnetic deviation. But he was to return to the deviation of direction-finders early in the 1920s and would then treat the

problem with great scientific rigour and completeness. The results were partly published in the *Maritime Journal* in 1925 and 1927, although the bulk of the work remained in the navy.

The experience of radio reception and radio-direction-finding was a splendid school for Berg. It perhaps made him one of the foremost radio experts. You can hardly have a better head of a project than one who started from scratch. Invaluable are a general who has risen from ranks and a manager who has risen from a factory hand.

Berg started with learning to assemble, dismantle, repair and adjust the primitive hardware available during World War I. Later, after the revolution and civil war, Berg would graduate at the Naval Academy and would become a professor of radio engineering, an Academician. But even back in 1917, without an adequate schooling in radio, he had learned much by hard experience, which formed the foundation for his further creative growth, the experience not to be derived from a university or an academy.

Berg explained: "A radio technician cannot manage just with pure theory. To become a real radio specialist, or a radio man, as they say, one should solder up many a circuit, should breathe life into many a radio set. One should perceive the beauty of the seemingly pointless tangle of wires, resistors, capacitors, inductors around radio valves, should perceive the fascination of suspense: now a voice will be heard, caught by your device from thousands of voices deafening the world."

Berg fell in love with radio from his early days on the submarine, in the dangerous war-time sea, among mines, with the enemy round the corner, when he was slaving over a primitive radio set trying to make it receive time signal sent out by the Eiffel Tower and Nauen.

The Last Operation

And still E-8 came to grief.

"I've been on E-8 on eight missions," recalled Berg, "but we sank not a single vessel, although attacked several times. We stalked, chased, attacked, did tricks, and hid. The risk, hazards, are the same. Just bad luck."

But rather, the reason was that E-8 was in bad repute with the Germans and under special surveillance. A month

before the coming of Berg, in the summer of 1916, the submarine under the command of the fine English officer Goodhardt had sunk off Libava the modern German cruiser *Prince Adalbert* with its crew. That had been the talk of the town in the Baltic Fleet for quite some time. The E-8 had really carried out a brilliant operation, having stalked the *Prince* when she came in the Russian waters to lay mines.

The Russian intelligence got the wind that the *Prince Adalbert* had steamed out of Memel to Libava, which by that time had already been occupied by the Germans, where she had to take on board some mines. The E-8 had been ordered to sink the cruiser at the exit of the port. The sub hid itself off Libava, and Goodhardt through the periscope spotted three funnels on the horizon. The *Prince* was coming.

The submarine waited patiently for the cruiser to pick up the deadly cargo and to leave the port. But the Germans took their time. Fuel ran low on the submarine, but the *Prince* would not belch smoke under the cover of the waterbreak and shore batteries. Goodhardt was in good mind to back out—three days to get to Revel. At length, accompanied by four destroyers *Prince Adalbert* pulled out of the harbour. She went in the range of Libava light-houses, between two mine fields. The E-8 tip-toed between the destroyers and put two torpedoes into the German. The ship exploded with its crew and the cargo of mines. The terrible explosion damaged the E-8. Her hull was in bad shape, she lost control and was expelled up on the surface under the fire of the German destroyers. Two or three days the sub was furiously chased by the Germans, she zigzaged, lay on the bed. Oxygen was nearly out, as were fuel and food. She hardly made the port, but the crew were so exhausted that they had to be partially replaced. Commodore Goodhardt was awarded with a St. Georgy Cross and an English Officer's Cross and left for England. The Russian navigator Pavlov, Berg's predecessor, was awarded with a St. Vladimir with Swords and relieved from the submarine. That was the Pavlov, Berg knew from his days on the *Tsesarevich* and earlier still at the naval corps.

After that resounding victory, the Germans were on the hunt for the E-8. The new captain and navigator were having a hard time, the enemy was on the look-out. And quite

soon, in one of the first missions in which Berg was already taking part, the submarine was ambushed at the exit from the Gulf of Riga to the Baltic Sea. She was progressing along a narrow and winding channel of Solouzund between the islands of Ezel and Dago. In the fog no reference marks were seen and the submarine hit the ground. Berg, who was plotting the course for the cruise, was down. He felt a soft push and rushed up onto the bridge. The captain tried to set the sub afloat by backing and by filling the stern tanks, but the shallow was too gentle and the attempts were abortive. When the fog scattered, the Germans had a beautiful target and they opened fire. That was a terrible moment because the submarine was helpless. Fortunately, the Germans did not dare to come closer because the Russian shore batteries were answering, and the Germans stayed away from their range. The submarine was lying on a bank, the crew could not push it away on their own. They were in need of help. It was decided to send Berg and two men ashore. They launched a dinghy and under the fire set out on a desperate voyage. The last meters to the shore they waded neck-deep—beyond a wide spit, on which they had to leave the boat, the bottom deepened again. Soaked and covered with mud, they went in the opposite directions in search of shore stations, about which nobody had the slightest idea. When some of them reached a station, they telephoned to the authority concerned and asked for help. Only in a day came three destroyers and a big tug-boat.

The brand-new destroyers sailed past the miserable submarine on to the open sea and drove away the Germans. The tug-boat removed the poor E-8 from the shoal. But the real disaster came much later.

The enemy still got the E-8. In October of 1917 Berg went out on his last mission, from which he returned seriously ill. After an especially long chase, the main electric motor caught fire. The sub could not surface and the crew were poisoned by toxic gases. The E-8 was brought to Helsingfors, a miraculous escape.

The unconscious Berg was brought to a hospital, E-8 was quickly patched, the crew were replaced, and the submarine again went out on a new cruise with a new navigator, Berg did not return to it any more. When he was in the hospital, the Germans got as far as Hanko and landed troops there. The Russians had to leave Finland and denude the Baltic

front. Helsingfors was doomed. The sailors who served together with Berg managed to carry him out of the hospital and to pull Nora and Berg through a window of the last train bound for Petrograd.

The Icy Cruise

So Aksel and Nora, without their belongings, nearly without money, escaped from Helsingfors and came to Petrograd. That happened just several days before the momentous events. The political atmosphere in Petrograd was full of electricity, like before a storm. And a storm, a cleansing storm, came. It was the October Revolution.

Berg was 23, but after the intoxication he developed a serious cardial disease, and so a medical commission pronounced him unfit for submarine service.

He had had a solid experience of a combat navigator under his belt, but who cared for this on land? How to dispose of oneself, what to do, where to apply his knowledge and experience? How to live, and how to earn his living?

Perhaps for the first time Berg had sufficient time to ask those questions. After the naval life filled to the brim he appeared at a loose end, idle and helpless.

Happily, in Petrograd he met his old colleague from *Tsesarevich* days Captain Vladimir Belli. *Tsesarevich*, that old tub consuming too much fuel, had already retired by the time, and Vladimir Belli was transferred to a new destroyer, still under construction, that was named *Captain Belli* after Vladimir's great-grandfather who served in the Russian navy under Peter the Great, and faught successfully against the Swedes. And now the great-grandson of the Peterian hero invited Aksel to the post of the navigating officer and to act as the senior officer until the crew would have been staffed before the commissioning of the ship.

The ship was still in the yard, this suited Berg perfectly, because after his intoxication he was still too weak. On the *Captain Belli* Berg made only one mission. That was already during the time of the foreign intervention, when it was necessary to remove the ships being constructed away from the Putilov shipyard, which appeared to come within the range of enemy gunfire. The ships that could not move on their own were tugged. Belli and Berg brought the de-

stroyer to the Nikolai Bridge, beyond the reach of the enemy fire. When the danger was over, the ship was tugged back to the yard.

But that was later.

The cushy assignment on the *Captain Belli* enabled Berg to restore his health quickly. In Petersburg he was away from the political isolation to which he was doomed by the fate when he stayed on an English submarine. Petrograd was seething, rallying, fancying.

Berg plunged into disputes and debates, started attending meetings. Here one could meet a wide variety of soapbox preachers, coming from all political parties and groups. Healthy intuition, culture and the flair of a Russian intellectual enabled Berg to make the correct decision, to side with the Bolsheviks for a new Russia.

He was especially impressed by V. I. Lenin's speach at the First All-Union Congress of the Navy on 22 November 1917. That address explained much to the seamen and decided the hesitating ones. It was at that time that Berg got involved in revolutionary activities. He got a new appointment. Still belonging to the crew of the *Captain Belli* he was attached to the Headquarters of the Baltic Fleet as an aide to the Flag-Captain, Operations. For a young man, a former czarist officer and a nobleman, this was an honour.

The Headquarters was then living an active life. Seamen constituted the most reliable part of the Armed Forces of the Soviet Republic. The navy was protecting Petrograd, the stronghold of the revolution. But new dangers lied ahead.

The provocative behaviour of Trotsky disrupted the peace negotiations at Brest-Litovsk. The German army on 18 February 1918 started general offensive along the entire front line. The Germans were striving to Revel to lay their hands on warships that were wintering there.

Lenin forsaw that possibility. On his suggestion Sovnarkom (Council of People's Commissars) already on 17 February sent to the Centrobalt (Central Council of the Baltic Fleet) instructions to transfer the ships from Revel to Helsingfors and to prepare to assemble all the fleet at Kronshtadt. By the same instruction it was decreed that the defences of sea approaches to Revel and Helsingfors be reinforced.

With his experience of service on the Baltic front Berg was carrying out a number of important missions associated

with the realization of the Sovnarkom instructions. Under his surveillance on 22 February the last Russian submarines left Revel led by the ice-breaker *Ermak*.

Despite the fact that on Lenin's insistance on 3 March 1918 was signed the Brest-Litovsk Peace Treaty, the "filthy Brest peace" to use the words of Lenin, the situation on the Baltic Sea remained unstable. The Germans were violating the armistice. On the night of 3 April a German squadron entered the Gulf of Finland.

In the morning the German troops started landing near Hanko. Four Russian submarines were frozen-in there. Without ice-breakers it was impossible to bring them out. They had to be exploded. The submariners taught their way through to Helsingfors and joined the crews of the submarines there.

According to the treaty the Soviet government was obliged to disarm or bring out of Finnish ports all the warships by 12 April. The Soviet government was punctual in executing its obligations and followed the rule despite the fact that the other side violated the treaty.

In early spring the Gulf of Finland is always covered with ice. No navigation in it is possible, and the Germans counted on capturing the fleet at Helsingfors, but the Centrobalt appealed to seamen to save the ships of war.

The Headquarters of the Baltic Fleet assigned for this operation, which went down in history under the name of "Icy Cruise", the most reliable and skilled red commanders and commissars. Berg, as an aide to the Flag-Officer was carrying out errands associated with the control of that prodigious mission.

Despite all the difficulties, the last ships left Helsingfors on 7 April. Among them was the legendary submarine *Pantera*, which had taken part in World War I, in the revolution, in the struggle against the intervention, and in World War II. In May 1919 Berg was appointed a navigator to the *Pantera*.

The unparalleled epic was accomplished brilliantly. From Revel and Helsingfors about 300 warships came to Kronshtadt. The Soviet Baltic Fleet was saved and it served well to the country during the imminent intervention and civil war, and later during World War II.

Another fate befell the British ships that had faught side by side with the Russians before the revolution. At that

time Britain was planning a military intervention against the Soviet republic and the Sea Lords of the Admiralty did not want to have their ships brought to Kronshtadt to get into the hands of the Bolsheviks. The British government ordered to explode the British ships and submarines that were wintering in Helsingfors. So died the E-8.

Another Peaceful Lull

After the fantastic tensions of the Icy Cruise came a relative lull. Seamen were busy with the repairs of the ships and exercises. And all the country got a breathing-space. The Soviet power had a triumphant and nearly bloodless march over the vast territory of the former Russian Empire.

Berg continued to serve at the Headquarters and to act a navigator at the *Captain Belli*. But that double burden was insufficient for his vehement nature. He found himself having some leasure, a state, even at that time, intolerable for that man.

"The captain of the destroyer allowed me at my leasure to indulge in self-studies, which eventually brought about drastic changes in my life. I was fed up with blah-blahing that navies are not needed any more; now that we have aviation, warships and submarines are just bees in the bonnet. It was only natural that I started retrain myself, that is, to brush up on mathematics, astronomy, history, philosophy, and political economy. Self-education just for education's sake. Soon after the October Revolution a book-keeper's course turned up, I joined it. Would come in handy some time, I thought. But it was a deadly dull. The only kicks I derived were from the lectures on political economy and history of economic sciences, which were read very lively. And so I surmised that accountancy is not my cup of tea and joined the economics department of the First Politechnical Institute. Classes were already in progress, but there were no students. Once on a lecture on mathematical statistics I was the only one in a huge audience. I held council with my corps mate Senya Girenko and we resolved to join Petrograd University, Department of Physics and Mathematics.

"In the autumn of 1918 we were received by the dean of the department Gyunter. To me he gave a cool reception—I was 25, not that young. The corps sertificate with honours

was nearly ignored. But formally no exams were required from me, and I started going to the lectures. Students were few, mainly girls, daughters of university dons. Some only 18-19 years old, and I felt like an old man, the more so that I, alas, started to get bald.

"I regularly listened to the lectures of Professor Adamsky, an introduction to analysis. The old man was a tiny thing, and the blackboard was huge; from the long-term labours he buckled somehow, the right shoulder became much higher than the left one. His lectures were very good but we had to work under pressure—he was chalking atrociously fast and dusted away even faster—with no time left to grasp the gist of the matter. I was scribbling like crazy and was, perhaps, the only one who was in possession of complete lectures, but... I would have no time to study them. I was fortunate enough to listen to such a remarkable scientist as the physicist Khvolson. His books were held in high esteem both in this country and abroad, and were used by several generations of physicists. He read in the famous large physics lecture-hall, where Popov in 1895 had made his historic report. As far as possible, I tried and performed all the physical laboratory works, which were under the guidance of Vladimir Pavlov, a son of Academician Pavlov. Often we worked together with Terenin, later an Academician. I also got acquainted with Sharonov, who was later to become a prominent astronomer. Sharonov was a serious and thoughtful student. We were crazy about astronomy, and I often visited his small home observatory. After all, I went to the university in the hope to become an astronomer, even now I'm constantly attracted to it.

"I also remember Professor Stakhovsky who was our reader in integral calculus. He was an antiquity, awfully famous, and had difficulty in moving about and was at all times accompanied by his daughter. For some reason he treated us, students, as the accused and, interrupting his lecture, would start preaching at us, considering that we, the youths, are to blame for all that hunger and economic chaos. That was the time when events had split people up into two camps, and some, while continuing to attend to their old duties, had nevertheless lost the ground under their feet. One of them was Professor Kreshensky, a major specialist in theoretical mechanics. Before long he emigrated. I remember a note on the door of the physical de-

partment "Prof. Kreshensky receives at home never, nobody and on no business". This amuzed us and even surprised, since in those days the university was not heated, it was frosty indoors, the rooms were vacant and so it was general practice to visit the instructors at home not only for tests but also for lectures. So I had been at Professor Mesher-sky's of the First Polytechnical Institute for tests in theoretical mechanics. He lived at Sosnovka, in a large professor annex in the park of the Institute. I remember his dry, sinewy, red-bluish nodular fingers and his image, all hungry and cold. Despite the deprivations, he continued to work fanatically.

"Unfortunately, I could not regularly attend the classes, I was still serving in the navy. Therefore, I was allowed by Pavlov to work in the physical laboratory of the university on Sundays, and during Sunday I tried to catch up with the curriculum, by making several assignments at once working from morning till night alone in a huge empty lab. I remember how under those circumstances I was struggling with some work whose description was on a threadbare, torn sheet of paper and was cudgeling my head trying to grasp what was to be done, and there was nobody to ask. A watchman would come and give valuable pieces of advice, perhaps more valuable than an assistant professor could give—for decades he was serving at the laboratory and had seen dozens of times what students were doing."

Fight Against Former Friends

In the spring of 1919 the Atlanta imperialists embarked on their first crusade against the Soviet Republic. Having armed the Russian white guardsmen, Lettish and Estonian nationalists, the Atlanta sent the troops to places where landing was easier.

On 13 May 1919 commenced the general advance of the counterrevolutionary forces on Petrograd. The troops under General Yudenich breached the front between Narva and Chudskoye Lake, so menacing the city directly. The English ships entered the Gulf of Finland and were supporting the advance of Yudenich.

The Central Committee of the Communist Party called upon the entire country to help Petrograd. Petrograd workers were preparing the city for defence. Sailor detachments

were fighting in the most dangerous sections on the land front. A force of ships of the Baltic Fleet was supporting with its fire the offensive of the 7th Army in the sea-shore region and protected its rear from enemy amphibious operations. On 18 May the destroyer *Gavriil* and several mine-sweepers were engaged in a first combat with four British destroyers.

Under those circumstances a submarine navigator could not stay ashore. Berg arrived with his new assignment to the captain of the *Pantera* Alexander Bakhtin. At his 24 years Bakhtin was a veteran submariner. He had served several years on submarines and during the war had been senior officer of the submarine *Volk* (Wolf). Bakhtin had been in charge of *Pantera* only since 25 November 1918 but had been out on it several times. On the submarine formed an excellent crew, united, disciplined and skilled. Berg liked Commissar V. Ivanov, a Bolshevick since October 1917, and Senior Mechanic was V. Sauks, with whom the new navigator found much in common. He quickly felt at ease with all the crew, and some of them became his friends for life.

Berg's first mission on the *Pantera* was on the night of 24 June 1919. In the early morning fog the submarine went out into the Gulf of Kapor where the ships of the interventionists were cruising. When the fog cleared out on the horizon appeared British mine sweepers, they were engaged in control sweeping of the channel. Targets of minor importance, hardly worth exposing the submarine. *Pantera* was waiting.

Then the navigator found that due to the failure of the log, a velocity meter, just like a speedometer on a car, the sub in the fog had crossed the Russian defence mine fields. Berg immediately reported to the captain. The course was put right, but the submarine had to return through the same fields.

Bakhtin wrote later: "We were not discussing this with the navigator in order not to cause excitement in the crew. We understood each other silently. But the hour before we hit clear water seemed to me to be ages."

After having passed at full speed along the channel and found no hostile ships in sight, the submarine reentered the Gulf of Kapor. She submerged and steamed on under periscope.

At about 11 o'clock in the morning they spotted the periscope of a hostile submarine. It appeared intermittently to the starboard of the *Pantera*. Again small fry, and Bakhtin ordered to dive. Speed was reduced to the dead slow and the sub was progressing by dead reckoning. When in an hour the sub came up to periscope to survey the horizon, they found afore two submarines. They stood still in the surface position. The crew of one of them were bathing serenely, dead sure that no Soviet ship was going to disturb their quiet.

Two submarines were quite a target. Bakhtin made a decision to attack. He brought the *Pantera* into the narrow gap between the hostile submarines, and when to the farther one were only six cables he sent a torpedo at it. Then he turned the *Pantera* to the right and sent another torpedo at the other British sub. The attack turned out to be no success, however. The torpedoes dived and hit the ground.

The first British submarine immediately sent a return torpedo, but it passed astern. The second submarine was hastily retrieving her swimming party. Bakhtin decided to attack once more. He approached to four cables, the *Pantera* fired from both bow torpedo tubes. But at that moment the target submarine moved and turned. Both torpedoes missed.

After the volley *Pantera* did not stay down. The depth was insufficient, and water had no time to fill up the empty torpedo apparatus. And besides the helmsman was a bit slow in reacting.

Came the comand: "All who may to the bows! Depth twenty metres, hard a starboard."

Pantera dived while turning starboard. But before she had reached the safe depth diving shells started bursting around. The British, being on the surface, could quickly get ready for action.

About an hour the *Pantera* was playing hide and seek with the British, manoeuvring in the area of shallow depth. A depth of 15-20 metres was not enough for that kind of submarine, and she repeatedly touched ground with her keel. Only in an hour and a half they raised the periscope, but the glasses appeared to be misted and nothing could be seen. The submarine was surfacing cautiously to expose the portholes of the tower, suddenly deafening explosion came and Bakhtin commanded to dive.

Now the submarine was again tip-toeing between the

Russian mine fields. Berg was taking his bearings mainly following the relief of the bottom. Well, his life was made much easier by the fact that the *Pantera* was the first undersea craft on which, in addition to the magnetic compass, had been installed a gyrocompass. The gyrocompass, a technical innovation of that time, provided better accuracy of submerged navigation than the magnetic compass.

Now the survival of the crew and the ship depended only on the experience and skill of the new navigator. Berg was absolutely accurate in his calculations: the *Pantera* surfaced four miles from the Shepelev light-house near Kronshtadt. The British did not dare to chase her so far in.

The former friends became enemies. Could Berg imagine in 1916-1917 that he would seek to torpedo British submarines? And could the British seamen, who had liked him, imagine that their navigator would become their enemy? The British government, who had been an ally of Russia during World War I, after the October Revolution became her enemy.

Was It Hard?

Even in those days Berg was sitting for exams. Not during cruises, of course, but during his stay at Kronshtadt, although even then his life was far from cushy. The *Pantera* was moored at the base *Memory of Azov,* which was berthed near a gun-powder factory. Each morning, regularly, came Finnish or British airplanes, single or in groups. They threw bombs and arrows and tried to hit the factory. Seamen, however, accepted this with quiet, they would gather on the upper deck to watch that silly war—the British flew low and hurled bombs all anyhow. The forts and ships fired from their small-calibre anti-aircraft guns and machine guns. *Pantera* and other subs moored at the base were firing too to scare away the British. Arrows fell on the deck of the submarine base. Seamen were amazed at the absurdity of that show: those arrows were harmless for warships. But once a bomb hit a vessel, directly into the crew quarters and did much mischief there. Being aware that the submarines attract the British bombers and being afraid of the neighbourhood of the gun-powder factory, Bakhtin removed the submarine to safer place, closer to the battleships. Life became quieter.

Berg recalled: "In that relatively peaceful period I took advantage of each free minute to study, but all my records and manuscripts perished on the submarine base when it was hit by a torpedo when British motor torpedo boats attacked Kronshtadt in the autumn of 1919. My cabin was flooded. But anyway, I would have left the university. I quarreled with a professor of chemistry. I'd passed the test as I had been studying with thoroughness; and I had been quite prepared for the exam, but on that day of all days happened a tragedy that unsettled me for long. My friend Senya Girenko died. With him we studied together at the naval corps, together served on the *Tsesarevich*, and together entered the university. He was a charming person and an able mathematician. A tragedy in the Gulf of Kapor led to the loss of three Russian destroyers, an absurd and horrid development. This happened in August of 1919 near the Shepelev light-house, several miles off the shores. *Konstantin, Svoboda* and *Gavriil* got onto enemy's mine fields. At first burst one ship, the survivors of the crew jumped overboard and the other two destroyers started collecting them. Next another one hit a mine. And immediately thereafter, the last one. The horror was undescribable. Only two men survived. Senya died on the *Konstantin*, and we were to go together to take an examination in chemistry. You can imagine the state in which I arrived at the exam. And here the professor posed his question unclearly, I did not understand him and objected, and we fought. I was so hurt that I stopped attending the university at all.

"During that period it was extremely difficult to study systematically. The interventionists had their base on the Björkö, in the Gulf of Kapor were the British, they could be seen from the Shepelev light-house, near Sestroretsk were also the British. To the north of Kronshtadt, to west of Lisi Nos, were white Finns. The manoeuvres of each ship, even each submarine along the main range of Kronshtadt light-houses was clearly visible to the enemies. The Russian navy came to be paralyzed. Functioned only mine-sweepers, submarines and several destroyers. Each submarine had its job to do. It was well that on the *Pantera* we had such a united crew with complete mutual understanding, and we could fight successfully. How could I possibly desert them into academic life? And besides, the death of Girenko stamped my future life. I had to fight further, to revenge his

death, to drive away the interventionists, and only then could I think about studies."

In August of 1919 Berg was appointed captain to the submarine *Rys* (Lynx). It was with great grief that he bid farewell to the *Pantera* and her crew. But he was ordered to organize repair works on the *Rys*, to handpick the crew and to train them, in other words, to make *Rys* as efficient as *Pantera*.

The repairs were under way round the clock in the shipyard. The captain was only distracted from those repairs for training of young sailors. And even at that time he contrived to snatch some time for studies. Having come to grips with a wide gamut of technical questions and unfamiliar novel equipment, he understood that he needed profound engineering knowledge. Perhaps it was when he was teaching the novices that he felt his incompetence in many fields —a captain should be a navigator, a gunman, a mechanic, and an electrician. Partially, at least. Berg decided to become an engineer. Also, he was perhaps influenced by V. Goryainov with whom he served on the submarines. Goryainov, too, aspired to knowledge. They discussed sciences and had heated disputes about how one could combine love for the sea and ships with the desire to have some more universal profession, independent of vogue, of the spirit of the age, and of one or another attitude to the navy.

Aksel Berg related: "I decided not to come back to the university, and to take up technical sciences. On submarines I have dealt with electrical equipment, radio, internal combustion engines, accumulator batteries, navigation, deviation, radio direction-finders, sophisticated gyrocompasses. The Polytechnical Institute enjoyed a reputation of a good establishment, it had modern laboratories and skilled professoriate. And so Goryainov and I made our minds to enter the Polytechnical. Thus, in the autumn of 1919 I became a student of that establishment. But regular attendance of lectures was out of the question at the time. I continued to be in command of the *Rys*. We restored it and it went out on a number of training cruises. Only when the Gulf was covered with ice and on the submarine started winter repairs, could I from time to time escape to the town and attend the Institute. Unfortunately, the Institute lay very far from Glinka Street where I lived. City transport was bad, trams were rare. We used to walk and on an emp-

ty stomach—the habitual state then—that was unpleasant. After the walk we were terribly cold during lectures in unheated halls. And still I managed to pass tests regularly combining my studies with my naval service. And besides, I was sent to the submarine class of the Combined classes for naval commanders.

Was it hard? It was necessary to study—no time for arguing and brooding.

The Kaleidoscope of Labour

In the spring of 1921 Berg undertook an attempt to terminate his naval service in order to be able to graduate at the Polytechnical Institute. To achieve this in the strenuous atmosphere of the time was nearly impossible. But Berg made an attempt. On 8 April 1921 he submitted a memorandum to the Chief of the Combined classes Radus-Zenkovich: From the student of the submarine class Aksel Berg

Report

On the strength of the Decree of the Council of People's Commissars of 14 January 1921 and the Administration order of 26 February 1921 No 176 I kindly request you to send me to the electromechanical department of the First Petrograd Polytechnical Institute for graduation.

Navy man A. Berg

The memo was supported by the chief of the submarine class.

And the Rector of the Institute Professor Chernyshev and the dean of the department Professor Vorobyov also wrote to the Commander-in-Chief of the Navy of the Republic Nemitz:

"The Electromechanical Department kindly requests you to send navy man Aksel Ivanovich Berg to the First Polytechnical Institute for completion of his education.

"The Department deems it necessary to intercede despite the fact that at present A. I. Berg is a student of the Combined classes in view of exceptional abilities shown by him during his studies at the Institute. Despite the fact that Berg has been studying at the Institute under exceptionally difficult conditions, he has passed most of the obligatory tests to obtain the qualification of electrical engineer.

"Such rare perseverance, combined with exceptional gifts inspires hope that Berg would be able to complete his special education in a short time.

"It is beyond doubt that, should he receive a full engineering training, Berg would make a major specialist in the field of electrical engineering. In connection with the paucity of cadre this warrants the insistent request of the Department to send Berg from the navy to the Institute."

Another document was sent to the Commander-in-Chief, signed by the Chief of the Board of Higher Naval Colleges:

"The electromechanical department of the 1st Petrograd Polytechnical Institute filed an application to send the student of the Combined classes navy man Aksel Berg to the Institute for completion of education.

"At present, at the said Department a section of electrification of ships was opened to which only those who are familiar theoretically and practically with seamanship are admitted. The navy badly needs persons with adequate background in electrification of ships of war. For this purpose the most suitable candidate at present is navy man Berg, as regards both his outstanding abilities demonstrated during his studies at the Institute and his devotion to duty.

"Enclosing the correspondence on the subject and cognizant of the fact that navy man Berg, while at the Institute and then on practical work with foreign engineers, has learned much about electrification, I support the opinion of the Chief of the Combined classes and seek your agreement on sending navy man Berg from the Combined classes for completion of his education at the electromechanical department with retainment of his asignment to the Navy Commissariat."

Requests are always verbose, rejections are locanic. The resolution of the Commander-in-Chief: "Refuse for lack of specialists in the navy. Nemitz, 17.5.21."

The tough conditions of the first years of revolution make it nearly impossible to follow precisely the chronology of events. This would make the recount too patchy. The dramatism of the time piled one event upon another.

The navy again had to mobilize its forces, the enemies became active once more. In March 1921 Kronshtadt mutinied, stirred by the agents of the imperialist powers and counter-revolutionaries who managed to penetrate the Kronshtadt garrison. The entire country roused, casting off the

quiet after the recent triumphs over the interventionists and white guarde. The best representatives of the Baltic Fleet and Petrograd proletariat, headed by the delegates of the X-th Congress of the Russian Communist Party held at the time, quickly suppressed the mutiny. But not all seamen understood the import of the Kronshtadt happenings. The head of the Soviet state M. Kalinin went to Kronshtadt to explain the situation to the seamen. While returning from Kronshtadt he addressed the seamen in Petrograd at a meeting held at the conference hall of the former naval corps. Also present there were the students of the Combined classes, among them Berg. The clear, candid speech of Kalinin greatly impressed the seamen. They understood that the navy was necessary to the country, that not a single ship must be idle, and that even those ships that seemed to be hopelessly damaged must be made fully ready for action.

The restoration of submarines became the main occupation for Berg during several years. Once he had returned to life the *Rys*, turning it into quite a reliable submarine with a good crew, he was immediately transferred, or to use the language of the time "thrown over", to a more difficult job, the restoration of the submarine *Volk*. The *Volk* was in an extremely bad shape due to the heavy damages sustained in the hard campain of 1919, and its crew for the most part consisted of untrained sailor boys. True, they were new youth. Komsomol members came to the navy. Their enthusiasm was much to Berg's liking. Quite soon the restored *Volk* was returned to the navy fully fit for combat service. While the *Volk* was made shipshape and studies were continued in the Combine classes, Berg was charged with yet another emergent business. It was necessary to restore one of the most efficient subs of the Baltic Fleet, the *Zmeya* (Snake). The game was worth the candles.

At the time the *Zmeya* was the most powerful and fast submarine not only in the Baltic Fleet but also in the entire Russian navy. She was actually the only sub fitted with the engines as designed, 3 000 h.p. diesels. That enabled her to develop a high speed, 17 knots, whereas the other subs, with their 200 h.p. diesels, were crawling at 6 knots. It took only three months, but three months of unheard-of slaving, for the *Zmeya* to put out to sea. In October 1921 Berg was appointed captain of the *Zmeya*. Among others who distinguished themselves in that job, Berg was award-

ed for his work bordering on heroism the title of the "Hero of Labour of the Separate Submarine Flotilla of the Baltic Navy".

Berg proudly kept that modest diploma all his life. It reminded him of that overworked, underfed part of his life, when his service in the active navy interwove with shipyards and the Polytechnical Institute.

His service on *Zmeya* came to an end through an accident. An emergency preparation for cruise was under way. During an obligatory preliminary check of machinery the captain was reported that the electromotor of one of the periscopes was overloaded. Berg came up to the faulty periscope and found that the lifting rope had left a trace on the motor body, which was obviously responsible for the overload. Berg poked a finger of the left hand into a gap to check the tension of the rope. At that moment, as bad luck would have it, the torpedo artificer, who was checking the equipment in the conning tower, switched on the hoist of that periscope. He, of course, was unaware of what was happening below. And below, the suddenly strained rope cut into the finger of the captain. One phalanx was immediately torn away, blood gushed from the wound. Berg automatically took up the severed part and wrapped it into a handkerchief. Only then he bandaged the finger with another handkerchief and went upstairs making for the first aid.

At that very moment, the signaller called out that the flag ship had a signal up "*Zmeya* to follow to destination".

To the first aid Berg got only in 18 hours. The result was blood-poisoning, hospital, an order with commandations, and after the hospital, late in 1922, a medical commission and an order dismissing him from active service in the navy because of the poor shape of his health. The reason, of course, was not just the finger alone, but the drastic impairment of the general state of his health as a cumulative result of the intoxication on the E-8, the enormous overstrain of the last years and the heavy sepsis after a seemingly trifling injury.

Chapter Six

Beginnings

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Assault

A combat commander, devoid of the possibility to continue his active service not only on submarines but also on surface ships, had before him two well-trodden paths. The first one was to carry on his service at headquarters and offices. The second was to appeal for retirement and become a civil servant.

The first course disgusted the entire energy-laden nature of a man fond of machines. The second was unthinkable for a professional mariner. Of course, if it had been possible to become a navigator in the merchant marine, Berg perhaps would have given a thought to that career. But the young Soviet republic had practically no merchant fleet. And he just could not give up the sea totally.

Berg decided on a third path—the only one that enabled him, without separating himself from the sea, to pursue science and technology, or rather radio engineering, which was attracting him ever stronger and stronger. There was only one way of realizing his intentions—by joining the electrotechnical department of the Naval Academy, where for the first time a division had been organized concerned with the new domain of radio.

That was tempting, here he could apply all his knowledge and powers developed by the many years of persistent self-study. Berg realized that now more than anything else in the world he wanted to join the Academy.

To want is the key to any unassailable summit. How could a man who was resolved to achieve his goal be baffled by the fact that the Academy required an engineer's qualifications and a long list of passed examinations? Well, if it must be done, it will be done. Some exams not taken—well, they would be. They must be.

And Berg signals for himself a new combat operation—the assail of the Academy.

To be sure, resolution alone was not enough, the task called for perseverance, patience and even ingenuity. Speed turned out to be nearly the most important factor in that campaign.

But by that time Berg had already acquired sufficient experience of intensive, crash studies. Few could have maintained the tempo he had taken since the autumn of 1919, when he first started to combine his naval service with studies at the Polytechnical.

The Combined classes, which the captain of the *Volk* attended in 1920-1921, were located on the premises of the Naval Academy on the Vasilyevsky Island. Across the street was the 2nd Polytechnical Institute. And so Berg managed to attend lectures there and to take tests and exams in courses that coincided with those at the 1st Polytechnical. The laboratory works and the theory of diesels he tackled at the Technological Institute, since a professor of that institute was also reading at his submarine class.

And the laboratory works on alternating current he did in the Mining Institute, where Professor Lachinsky of the Polytechnical worked.

Why such a tangled arrangement? Because he was saving time—the submarine base to which his *Volk* was attached in the summer and autumn of 1921 was berthed near the Mining Institute. The same pace was maintained after Berg was appointed to *Zmeya*. And now, by the end of 1922 he had passed many exams for the university and all the exams for the four years of the Polytechnical. But officially that all was not enough for his enrollment to the Naval Academy. The Statute required that to be entitled for enrollment all the students be possessors of a diploma of the Higher Naval Engineering College.

Before the revolution the Naval Academy had been producing several dozen officers annually for work at the General Staff and had by no means been an engineering establishment. It had only supplied general knowledge of tactics, strategy, naval history and navigation. It had been churning out snobs of seamanship. That had always been disastrous for the Russian navy. Now it was not to be tolerated any more. The Academy was to be technicised and made more connected with the present-day needs of the navy, which was being filled with novel machinery and devices.

In 1922 the Academy opened up new departments of engineering profile: electrotechnical, ship-building, hydrographic—the unheard of thing for the Academy. The Soviet power was creating a new Academy.

The Academy was staffed with naval commanders with extensive combat experience and sufficient engineering background. Berg had both, except for a diploma. He was admitted on the condition that during the first year at the Academy he would receive the necessary diploma.

Another year of stubborn studies, and already in 1923, having passed several exams and having defended his diploma work, Berg graduated from the electrotechnical department of the Higher Naval Engineering College and received the qualification of electrical engineer of the navy.

One might imagine that now came the time of quiet academic life, but the rearrangement of the Academy was not progressing that smoothly. It encountered resistance of the old professors, some of them being even major scientists. Many of them were readers in naval disciplines, although they themselves had not served in the navy; they had been designing ships and submarines, but never sailed on them. They not only were unaware of the needs of the navy, but even did not believe in it. They were not only against the new technology but believed that Russia needed no navy at all. Young officers who came to the Academy from the active fleet put up a fight for the navy. They faught with the dash of hard-core fighting men. Berg was among the leaders. He was known as one of the most temperamental disputers.

Perhaps because he grew fond of submarines, he was struggling not only for the navy in general, but mainly for the recognition of the dominant role of underwater craft in a modern naval warfare.

Berg would say: "Having faught on submarines since 1916 I've seen that surface ships are absolutely helpless in the face of submarines. And many of our 'specialists' know ships and submarines only from drawings and pictures, and now they are expatiating with an academic air about naval policies. How possibly can these policies be right? We should struggle against them."

Berg related later:

"I had been reading everything which I could find about the history of marine engineering, my weapons were exam-

ples, facts, statistics. And, so help me, sometimes I gained victories. Especially in open discussions. It is much more effective to fight openly—everybody sees that your opponent is incompetent and his judgements are not objective, that his knowledge is inadequate, and therefore he is wrong. By the way, at the time it was not accepted to speak from paper, smoothly. We argued. And the truth was born in the dispute. I just could not remember among my companions people who did not care, everybody was anxious, the career we have chosen we regarded as our personal, vital cause. And it was immediately apparent who was clever and who was stupid, and that is so important if you want to win a fight for a just cause.

"Amazingly, several decades would have to pass—decades!—for everybody in the world to understand at last a truth that to us, submariners, had long been clear. At length, they mostly stopped building battleships. Now the power of a navy and its efficiency is governed by the quantity and quality of submarines fitted with atomic missiles. But how much effort was wasted in press and oral discussions to protect the submarine fleet. We won with our love, enthusiasm, and we, the young, were listened to, although we were not academicians and admirals."

The discussions at the Naval Academy bore fruit. The talks that the submarines were not needed gradually abated. It was considered the immediate task to introduce into the curriculum courses that would give practical knowledge to future Red naval commanders.

On 4 March 1927, the five-year anniversary of the new Academy, the newspaper *Red Baltic Fleet* devoted to that occasion nearly a whole issue. The lead said: "Today the Naval Academy of the Red Army of Workers and Peasants is five years old. We are celebrating the five years of our Red Academy whose establishment and five-year history are a result of our creative work. Not the caste of noble aristocracy but sons of workers and peasants form the student body of our academicians. Nearly all of them have passed through the tough experience of the civil war and have proved their absolute devotion to the revolutionary cause. The working people of the country can rightly be proud of them."

The Chief of the Academy B. Zherve wrote: "Having contributed its best forces and material means to the civil

war and having no opportunity to recuperate, the Red Navy by the end of the war had been totally exhausted. For the Soviet government the question came to a head and energetic measures were taken to restore the navy's fighting power. The IX Congress of Soviets has declared this task as a burning problem for all the working people, and above all, for old navy men, hardened fighting men of revolution and civil war. During the civil war the old Naval Academy appeared in its deep ideological rear and, devoid of the fruit-bearing foundation, was dying out slowly. But now we have at the Academy 24 laboratories, equipped according to the up-to-the-minute scientific requirements."

There was a large photograph in the newspaper: "The radiotelegraphic room of the Academy". Near a valve radio receiver of their own manufacture stood: Aksel Berg, the head of the laboratory Vladimir Kazansky and Aleksei Grinenko-Ivanov.

Berg and Grinenko-Ivanov were nearly the only radiotelegraphist-students at the Academy. The first enrollment included only three of them. The third one was N. Suvorov, to whom Berg would soon express his acknowledgements for his looking over his third textbook. Yes, the third one, although it was written immediately after the second one, and the second one nearly concurrently with the first text, a fact striking even for the early 1920s. A student combining his studies at the Academy with teaching radio engineering at the course of telegraphic NCO's and teaching at two higher military colleges simultaneously, and writing for each of them a textbook. For NCO's it was *Vacuum Devices*, issued in 1924; for the electrical department of the Military Engineering Academy of the Red Army that trained electrical engineers, for whom radio was necessary to widen their horizons, *Cathode Valves*, 100 pages. And for the Naval Engineering College *General Theory of Radio Engineering*, 350 pages.

In the preface to the last book Berg wrote: "The course is shaped according to the curriculum and objectives of a naval college, which trains engineers for the navy. Therefore, most of the examples are borrowed from ship life and great attention is paid to oriented (*sic*) radio engineering."

And then come the words that largely explain such a progress of a student: "During the writing of the course I

repeatedly took advantage of the advice and recommendations of Professor I. Fraiman, to whom I am profoundly greatful for the assistance rendered."

With Fraiman

That man played a decisive role in the formation of Berg as a man of science. Imant Fraiman was the Teacher of Berg. A teacher with a capital "T" and perhaps the first teacher, despite the fact that the student was already a mature man, quite formed by his life's experience.

Professor Fraiman at the time was doubling as an instructor at the Electrotechnical Institute and he was responsible for reception of equipment in the ship-building department of the Naval Technical Committee of the Red Army. This made him a possessor of profound theoretical knowledge well acquainted with radio equipment of the navy. And it was only natural that when the Academy was looking for a head of the chair of radio engineering the choice fell on Fraiman.

Fraiman was a handsome young man, shy and reserved. And he was a prominent scientist, a self-made man in radio. He was cracking its puzzles with abandon and much of that quality rubbed off on his younger colleagues. The Professor got on with them splendidly, since he was nearly the same age, just three or four years older than Berg and his mates. That made it easier for them to become friends and to conduct, nearly as equals, their joint scientific work.

It was the happiest period of Berg's life. He was concentrated on one thing, could devote all his attention and energies to it. After all his strivings, his tense desire to combine his duties as a naval commander with studies, for which he only had odd moments, he with relish flung himself into scientific work.

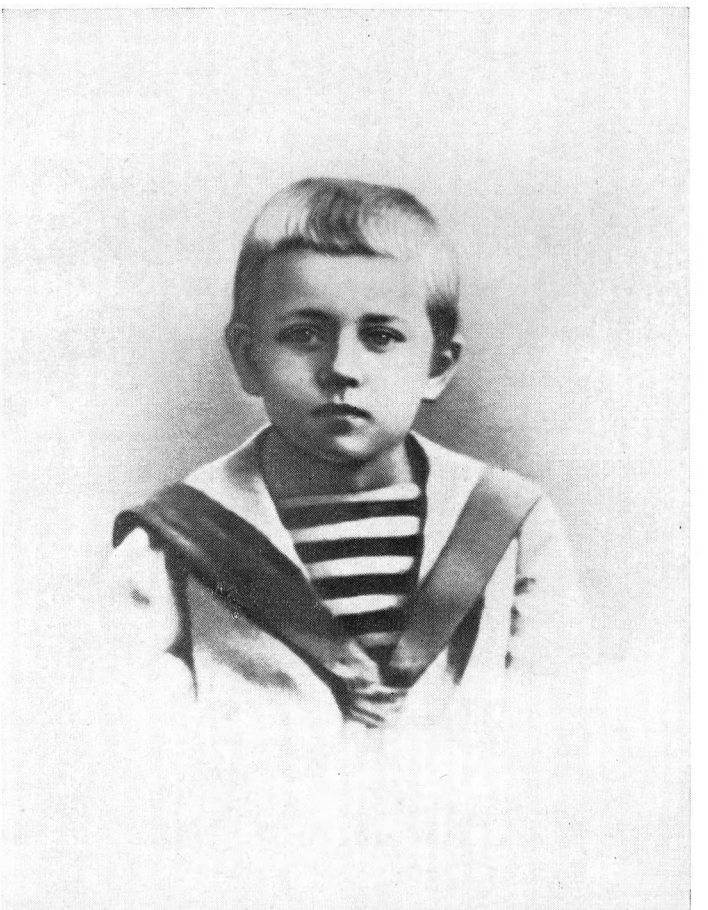
He still rose earlier than anybody at home. At five o'clock in the morning he was already working: till eight he had to prepare for lectures and seminars on fundamental disciplines. All the remaining time was devoted to radio. Fraiman arrived at the laboratory at nine sharp, some time they devoted to discussion of problems they had met with recently, then each went to his own working place. Each sat at his table littered with radio parts, coils of wire, solderers, all manner of frames, and half-assembled circuits.

Family of General
Iohan Berg (1890)

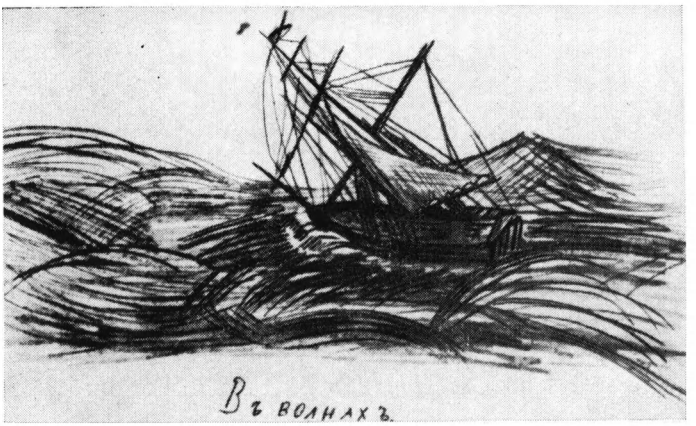
Iohan Berg

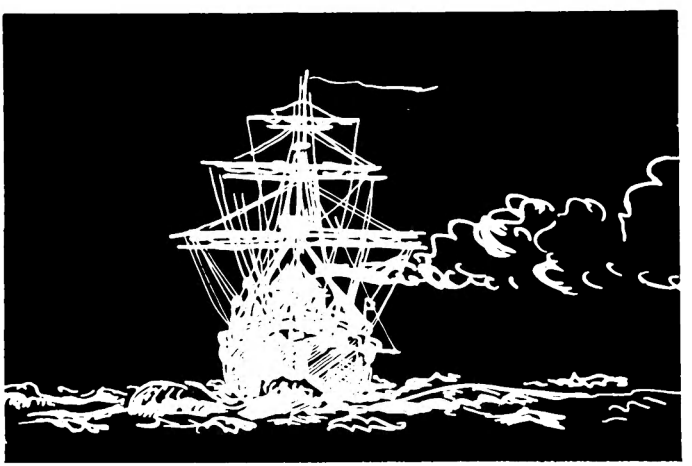
Elizaveta Berg

Aksel Berg, aged 6

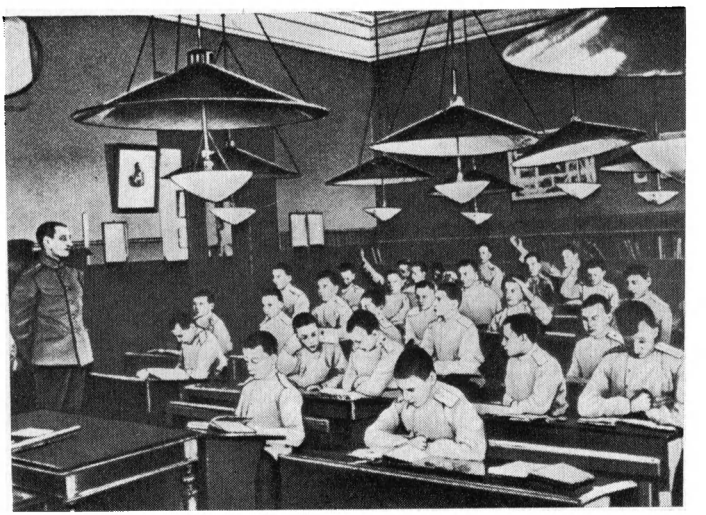


As a boy Aksel
liked drawing ships



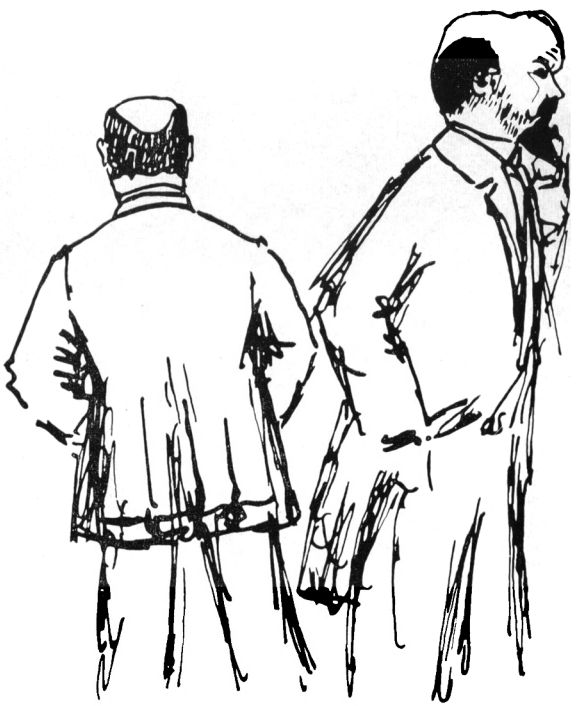


At the Alexander
Cadet Corps



Aksel with sister
Dagmara (1904)

The teachers
at the Cadet Corps (A drawing
by Cadet Aksel Berg)



Cadet Sasha Kornilov

The room filled with silence and smell of rosin. Even when somebody started to sing, whistle or discuss some business, for Berg it still was silence and quiet.

A result of the early scientific work carried out by Berg under the guidance of I. Fraiman was an article published in *Naval Journal*, number 8, 1924, entitled "Importance and uses of vacuum devices in radio engineering". The work concerned the radio valves and designing circuits with them.

Valves form the subject of both his early work and later research. Using rigorous mathematical and physical methods Berg had been cracking one burning problem after another. He was developing techniques of designing receivers and transmitters. Berg strove to make those methods simple, graphic and accessible to radio engineers in the field, to make radio an engineering science. Berg's methods are considered classic, and they are still in wide use despite the fact that today's electronics bears so little resemblance to the electronics of those days.

The student was catching up with his teacher very fast. Although the textbook on radio devices written by Fraiman in 1920 was much more advanced than the earlier texts by Petrovsky, Menshikov, Muravyov and others, by 1924 it became already a bit dated—the wireless was making anormous strides at that time. Berg helped him in preparing a second edition. In the preface to the second edition Fraiman wrote: "In that difficult work I was able to enjoy the kind assistance of my close colleague in teaching the special course of radio engineering at the Electrotechnical Institute, A. I. Berg. It is with especial gratitude that I must acknowledge his assistance."

In the summer of 1923 Fraiman decided to test his disciples in a practical business. He organized for them a special expedition to Sevastopol. Berg, Suvorov and Grinenko-Ivanov got an assignment to fix underwater communications on the submarines of the Black Sea Fleet.

Communication was done using isolated frame networks submerged when a sub was half-submerged or steaming at a small depth. Something familiar, isn't it? Yes, Berg did this on his own during his E-8 days. Those experiments answered perfectly to his earlier interests and he got totally absorbed in the work. But that seemed insufficient to him. He decided to repeat some of his direction-finder experi-

ments of old days; he managed to conduct some new experiments and continued them in the next expedition. As a result, in *Naval Journal*, number, 2, 1925, appeared an article "Significance and uses of oriented transmission and oriented reception in radio engineering". The subject-matter was extended by studies of directive aerials installed both at the receiving and transmitting stations.

At that time it was uncommon for students to be involved in active research. Ordinarily, students' works were just illustrating lectures. They were repeating what had at some time been discovered in enormous pains by trail-blazers but had long become routine. Those works only called for one thing, to help students to get their hands in at the subject in question. But radio in those days had not yet accumulated much truths of its own. And so students and professors alike were at the same time pupils and torch-bearers, and their findings laid the foundations of the science to which they devoted themselves. That was why the early works of Berg's were also those discoveries on which later generations of radio engineers drew heavily in producing the present-day richness of electronic industry.

The next summer season Fraiman and his disciples worked on a radio station solving the problems of telecontrol. Distant control of airplanes and ships at the time seemed to be a piece of science fiction even for men of science. Few were informed of the activities of several small groups who were pursuing those pioneering research investigations. One of the groups was that of Fraiman. He worked in contact with the bureau of Bekauri, who had been working on distant radio control of motor torpedo boats, torpedoes, and high-explosive mines.

Alexander Shorin, one of the most prominent experts of the time, organized the Central Laboratory of Wire Communication, a research institute of an exceedingly wide scope, which vied, in particular, with Bekauri as far as motor torpedo boats were concerned.

In Petrograd worked Nirenberg, a brilliant engineer and designer, who reported directly to Marshal Tukhachevsky. Nirenberg persuaded Tukhachevsky to initiate a programme of distant control of airplanes from ground. Under Nirenberg were about twenty young engineers of various specialities. Fraiman decided to sent there his students Berg, Suvorov and Ivanov.

That also was not an ordinary student practical work, but real research. They themselves assembled radio devices, still rather primitive of course, and then took part in testing and modifying them. Fraiman was of the opinion that a specialist is formed not so much by lectures as by practical activity, and he was doing everything in his power to have his students exposed to the latest developments, so that they could try their hand in manufacture and, in general, to gain first-hand experience. So Berg worked at a factory, where he was personally manufacturing radio valves and performing all the operations of a workman.

At the End of the Range

The electrotechnical department of the Academy was gradually attracting new instructors. For the course of electromagnetic oscillations Fraiman invited Professor A. Petrovsky, an outstanding expert and reader, the author of an early text on radio. Also came Nikolai Tsiklinsky, a prominent figure in the history of Soviet radio. He was a main designer at a factory where radio valves were manufactured manually, and he would bring those curiosities in his pocket to show them to his students.

Before long at the Academy appeared the generator valves of Mikhail Bogoslovsky. He was an electrical engineer, a Polytechnical alumnus and also a fanatic of radio. He started makeshift production of the first valves used to generate radiowaves. Once Bogoslovsky presented Berg with a 400-W generator valve. Its photograph appeared on the cover of the book written by Berg.

Other teachers of note were Viktor Volynkin, a valve man and Valentin Vologdin, who read in high-frequency machines and took part in the construction of the early high-power radio stations. Berg became friendly with the remarkable theoretician, experimentalist, designer, and also pianist and composer, Robert Lyuter. He was an engineer at Elektrosila works. It was under his guidance that Berg performed some of his student's designs.

The relations of the Academy dons with the students were highly unusual for these days, when institutions of higher learning are churning out hundreds of specialists annually. Lectures were few. The main concern of the electricity students was where to get the literature, the valuable

components and valves. Professors were treating them not just as fledglings, but as colleagues, mature people.

All of them were in the same boat, were generously sharing their experience, were playing on rare articles and books on radio. The journals *Telegraphy and wireless telephony* published by a radio laboratory at Nizhni Novgorod and the American *IEE Proceedings* were the most popular literature. Many radio engineers were working on design techniques for real devices. But there were no complete theories and methods of designing valve circuits. And so Imant Fraiman with his associates concentrated on those subjects. Other groups were those of Mikhail Shuleikin at Moscow, and Mikhail Bonch-Bruevich at Nizhni Novgorod.

They were doing radio engineering nearly from scratch, they were blazing the trail.

Another shock for the then unsteady foundation of radio communications came in 1923, when appeared evidence for short waves. Not a single station in the world used them at the time. Short-wave communication was thought of as unpromising. SW were only used by some amateurs. To toy with SW transmission and reception was considered an eccentricity. And suddenly, radio amateurs hit on a shocking thing: the range of SW communication appeared essentially unbounded. A radio enthusiast from Russia might pick up England; from England, India. Nobody could account for this. Physicists too had not yet investigated the tricks of that range, and the amateurs were the only people who could shed some light on the peculiarities of SW communications. Short waves became all the rage with mature experts. Berg was one of the first to construct a radio set and to install an aerial on the roof of his house. Once he picked up an English station.

That was a sensation in the Academy.

Especially happy was Fraiman, he was quick to grasp the enormous potential of radio amateur communications and he protected the enthusiasts from attacks of those who considered that pastime sheer waste of time or even "banditism on the air". He contributed to the creation of a nation-wide radio amateur movement. So he wrote:

"To be sure, we would be happy to see radio finding its way into all walks of life, so that there were not a single corner not covered by radio communication network and that there were no people who had no idea of radio. One

can multiply examples of the most wide possibilities of using radio, besides direct radio communication service, for a wide variety of cultural ends. The urgent necessity of the maximal possible use of these potentialities now that the country is thirsty for education and when it can receive several other cultural ways of amusements and pastimes at leasure, should be promoted by all means. For the 'radio movement' to become stable, it is necessary that hundreds and thousands, virtually the masses, take part in it. After all, there are hunters, anglers, mountain climbers. It turns out that there are also radio enthusiasts. If the former gave much valuable information to zoology, botany, and geography, the latter might be yet more useful to our radio engineering by gleaning all sorts of experimental data and by providing direct support to our radio industry."

Not Indefinitely

Prominent among the professors of the Naval Academy was Aleksander Fridman. In those difficult, hunger years he was in solitude tackling the most complicated problem of the development of the Universe. He was the first to suggest that the Universe was expanding as a soap bubble, and that it had had its beginning and that it would have its end. Fridman's conclusions were so audacious that Einstein, whose Relativity served as a starting point for Fridman's arguments, got interested in it. True, Einstein made a mistake in his calculations and criticized Fridman's speculations. But later he gave another thought to the problem and sent a letter with apologies and an article in a journal where he recognized the works of the Soviet physicist as extremely important and valuable.

But most of Fridman's colleagues, students and friends knew nothing about it.

I asked Berg: "The 40-year anniversary of the remarkable discovery of Fridman was recently marked by men of science throughout the world, why had you then overlooked it?"

Berg explained: "At the time some re-appraisal of values was in progress, one could overlook the work by Fridman, that was, of course, of immense importance for mankind, a work of major proportions, and at the same time be completely absorbed in the construction of the new life and

solve the most burning problems of the day. But about that work we knew nothing indeed, and it was only after his death that we learned. He died quite unexpectedly, quite a young man. He was reticent, secretive, we even had no idea that he was ill. True, he was a bag of bones, rangy, sallow."

"Was he really telling you absolutely nothing about his work on cosmogony, about how unusually he solved the equation from the theory of relativity?"

"Well, yes, he did tell, but somehow in passing. But we were not interested, we even took that as an eccentricity. We had our hands full. That only interested a few physicists who were able to look into those brain-twisting equations and to understand the beauty of his discoveries. But who then was interested in the infinity of the Universe? I, for example, to support my family worked in the mornings as an electrician at a factory. Then, I went to the lectures. After the lectures, I took off my uniform and ran to a weaving mill, where I also worked as an electrician.

"I, of course, got the allowance of a student of the Academy, but that could buy only seven pounds of bread a month. And I had to maintain mother, sister, wife and partially wife's parents. Nora also gave up her arts at the time. Art gave nothing to keep body and soul together. She worked at a hospital and at a plant as an apprentice designer. Having acquired the qualifications of a designer, she helped me much with the drawings for my textbook. Sister Margarita had by then received her diplomas from the mathematical department of the Teacher Training Institute and the electromechanical department of the Polytechnical. And still she had to earn something on the side. She, an engineer, worked with me at the weaving mill as an electrician. And nearly everybody lived that hard way. Students worked as dockers, or factory hands, and jumped at every opportunity to support themselves and their families. Money was then counted in millions, but was nearly worthless. Bread was the currency. And I 'ate' my favourite toy—I had a beautiful model of the ship *Moryak*. I exchanged it for two kilograms of bread.

"That was in 1923, and in 1922 after lectures I rushed to the submarine that was under my command. By the way, once Fridman and Smirnov, our teacher of maths, wanted to visit the submarine *Zmeya*. I brought them to the Baltic plant, where the sub was being repaired. They were amazed

at the complexity of mechanisms, the harmony of hardware and the sophistication of the organism of the ship of war. They seemed to have never before been to a warship, therefore, perhaps, *Zmeya*, which was perfectly designed, appeared to them to be a prodigy of technology.

"We met with Fridman at leisure, too," Berg returned to my question, "Nevertheless, he would not go into details of his pursuit. And as for Relativity, I just had no time for it. I had written a textbook, then a second one, and lastly, a third one, about 300 pages. You can imagine the pressure, under which I was working.

"Under strain lived both students and instructors. Therefore, you should not blame us for our paying no due attention to Fridman's work. And during his lectures the hall was generally packed like sardines. He read meteorology for navigators, and for us, radio men, non-linear mechanics. His courses were clear and interesting. We liked his classes very much, because they were very instructive. Meteorology at that time was hardly considered a science at all, especially in Russia, here we were hopelessly lagging behind. But he treated meteorology in mathematical terms, imparted to it the rigour of objective laws of nature, and made it into a real science. His lectures were necessary for practical activity."

Re-appraisal of Values

That phrase shows the mature Berg, who sought above all the practical value of any science, any art. In one of the discussions at the Naval Academy he formulated his viewpoint thus:

"It is for some reason believed that engineering is not so honourable an endeavour as pure science. Even engineers often do not understand what they are expected to turn out. And to be a good technician is not any easier than to be a good mathematician. However, many maintain that in such a hard time as ours, when it is not possible to apply one's knowledge to practice, one should retreat into pure sciences and accumulate energy to resurrect in several years, primed with ideas and science. This absurd view found its advocates in the Academy as well. It is only now that we should be able to apply our knowledge to practice. Just now we should find ways to raise the navy to the state-of-the-art

level. One could indulge in analysis and generalization, when everything would be arranged. But now life calls for active work and creativity, and to this healthy creativity the academicians should be inured".

"The main drawback of our engineers is their technical illiteracy. It is not sufficient just to be able to use curves and tables. It is necessary to have a technical scope, to be able to treat critically one's drawbacks and recognize them openly. Hence the tasks of the Academy are to produce workers perfectly knowing our Russian engineering life and its future outlooks, estimating our disadvantages reasonably and, above all, understanding that this cannot go on this way further. To produce experts knowing the foreign literature in their field, ones who have learned it perfectly and are able to apply the major achievements of foreign science to our conditions; ones capable of marking out new paths and able to work creatively and accustomed to heuristic thinking even within the walls of the Academy. The technical departments of the Academy must be the focus of modern technical thinking, they should illuminate with their light and their authority the entire navy. And here, having barricaded ourselves behind ostentatious scholarship, we have found the way out of the tragic reality in by-subjects stimulating the flourishing of abstract thinking. Are there really so few open questions in the ship and in machine-building? Are those open questions pasted up with mathematics? For lack of interesting leaders in their respective fields (of course, there are exceptions) students follow the path of least resistance and concentrate on abstract subjects, although guided by some really outstanding scientists and dons."

But for such a "pure" science as mathematics, Berg voted with both hands. He understood that students of radio needed mathematics badly, and without maths their fields would have degenerated to handicraft. Berg seems to have forgotten that during his cadets years the subject had been his sore point, one that had given him quite a few unhappy hours. Now he was so filled with confidence that sound knowledge of mathematics was necessary for radio specialists that he published in 1924 in *Naval Journal* an article "On the necessary volume of mathematics for engineering departments of the Naval Academy." Berg wrote:

"It is quite erroneous to think that electricians need ma-

thematics less than other specialists of the Academy. One proof of that is Professor Fraiman's course in radio engineering, published recently.

"In the theory of electricity and radio sciences maths found its elegant applications. Almost all the mathematical disciplines are applied in electrical engineering. Therefore, electricians, as representatives of a new science embracing nearly all the fields of modern knowledge clearly understood that their problems can only be solved through organized cooperation with mathematicians."

Just as later in his life he called upon technicians and psycologists, physicists and physicians to join forces in attacking the stronghold of cybernetics, so in the earliest days of radio he deemed it necessary to achieve a union of technicians and mathematicians.

He said:

"The problems facing an electrician are so diverse, the potentialities are so colossal that it is beyond one man to grasp all. The time has gone when one person could act as a calculator, a theoretician and a designer. And the time has come for team work. We will have to learn to find interfaces with colleagues and we will have to be able to organize collective efforts, so that a good engineer could rely on a good mathematician, and vice versa."

The article, submitted to the management of the Academy, reached its goal. The level of instruction in mathematics was improved. So, higher mathematics in the Academy was now read by Professor V. Smirnov, later an Academician.

Smirnov was a brilliant teacher, one who could bring material home to every student, so that everything would become interesting. Berg missed not a single lecture of his course and worked hard at compiling good notes. It happened even so that the course of mathematics loomed so large that it overshadowed all the other courses at the Academy. It was much wider in scope than was required by regular courses for engineering colleagues and called for much time and effort.

Smirnov realized that he aroused in the young mariner ardent interest in mathematics. And before long Berg became very intimate with the Professor. To be sure, the Professor was pleased that Berg, despite the enormous pressure, worked hard on his course. And Berg was eager to show that seamen were also equal to the occasion.

That devotion to mathematics, first under the influence of Betlingk, and then of Smirnov, paid off splendidly. In our days when we witness fast mathematization even of such fields as biology, physiology, psychology, the command of maths enabled Berg always to be on the frontier of the present-day knowledge. He was quick to grasp the importance of enriching traditionally descriptive sciences by quantitative analysis. Now many sciences are relying on mathematical analogies and models to account for the work of the nervous systems, heart, and living organism as a whole. Without mathematics it would be impossible to uncover the objective laws of mental activity of man, let alone the various problems in engineering—this all formed the foundation of the most modern of modern sciences, cybernetics. Cybernetics reveals common laws in the most distant fields: in the living organism and machine; in the heart and ordinary oscillatory circuit; in the brain and computer. A knowledge of radio alone would not have allowed Berg to grasp all the versatility and grandeur of cybernetics. And the decisive role here was played by mathematics.

It gave me a strange feeling leafing through the calendar of radio engineering of the 1920s. As a matter of coincidence, I am a radio engineer as well, I have graduated at the radar department of the Moscow Aviation Institute, and I am familiar with the names I encounter among Berg's associates. To us, students and later young radio specialists, such luminaries of science as Academician A. Mints, Corresponding Members of the Academy of Sciences A. Pistolkors, V. Siforov and others, seemed venerable patriarchs. Some of them we have seen and listened to at their lectures. Mickail Neiman read to us the course of radio transmitting devices; Iosif Gonorovsky, read general radio engineering. The textbook on radio receivers by Vladimir Siforov became thicker: at first it was a booklet, and when I was sitting for my post-graduate exams, it became thicker than a volume of *Encyclopaedia Britannica.*

Now, rummaging through Berg's papers and notes, I suddenly encounter those venerable men of science as boys, often painfully groping for an answer, but moving along with astounding perseverance.

Look back to only fifty years ago and you will find a radio virgin land beyond belief! In less than half a century radio made its way into all the pores of our life, and now

we cannot imagine our existence without radio. Without radio broadcasting we now feel separated from the world. Without TV most people just cannot imagine their leisure. Without radio control no spacecraft can be launched. A wireless in the form of a tiny pill is swallowed by a man so that his gastric juice can be analyzed, a radio introduced into the breast controls the heart. Radio has penetrated our life so thoroughly that even Fraiman could hardly dream of that in his time.

It is now clearly seen why Berg and all the raw recruits of radio engineering were so fascinated by that young science early in the 1920s; what they expected from it and dreamed of. Radio was not for them just a promising career or a suitable business. In the first place, it attracted them by its challenges, it was a focus of possibilities, which they, 20- and 30-year-olds, were eager to realize.

I think that today's students of radio do not experience even a fraction of what their colleagues of those days could experience—less novelty, less mystery. Problems do exist, sometimes even more complex and requiring more concentration, but there is no magic. No mystery, which surrounds only the unknown. All his life Berg would be thirsty for the novel, he loved the excitement of the novelty. Such was the case with radio engineering, with telemechanics, with radar, and with cybernetics. Let alone the alliances that, alas, give shudders to respectable cowards: electronics and medicine, mathematics and biology, psychology and cybernetics. These are the questions and problems into which he was to plunge later in the life.

A New Start

In 1925 Aksel Berg graduated from the electrotechnical department of the Naval Academy among its first radio experts. For the first time near the name of Berg appeared the word "radio". The Academy made a good job of hammering him into a real radio specialist. After graduation he was assigned to Moscow, to an administrative post at the People's Commissariat for the Military and Naval Affairs. He was to be in charge of communications and radio in the navy. A splendid career, it would seem. An honorary promotion for a young naval officer. But Berg was looking forward to returning to the navy to be personally involved

in providing radio communications. The administrative work in Moscow would have isolated him from practical participation in the radiofication of the navy. Berg would have had to say good-bye to his expectations, if it had not been for the intervention of the Chief of the Academy P. Lukomsky. He requested to change the assignment and to allow Berg to stay for post-graduate research at the Academy. The request was sent to the Commander-in-Chief of the Navy.

"His separation from the Academy and assignment to another city amounts to his total separation from scientific activities for a long period, since productive scientific work requires a laboratory, and acquaintance with the up-to-the-minute works and development at all plants of the radio industry, attending lectures and reports at scientific societies, following the foreign literature and having leisure time for independent theoretical work, which is impossible to combine with administrative work.

"During his stay at the Academy comrade Berg has carried out a number of scientific works that have found their practical applications. Furthermore, should he leave the Academy, he would be forced to discontinue his scientific and teaching work at the Military Engineering Academy and the Naval Engineering College. In the latter he supervises the graduate research in radio engineering of eight students.

"I deem it especially necessary to stress that the involvement of comrade Berg in the teaching and scientific activities of the Academy is now urgently necessary in view of the fact that, first, the scientific cadre at the Academy are few (and ever decreasing) and; second, that he has demonstrated unquestionable and great abilities in scientific and instructive work." ... And the request was rejected.

But Lukomsky was a stubborn and temperamental man, he knew well each of his graduates and often understood better than a student what he was equal to. He did not succeed in having Berg as a post-graduate student at the Academy, but Berg was left in Leningrad as teacher at the Higher Naval Engineering College.

On 16 March 1925 Berg received a diploma from the Naval Academy, which stated that Berg "successfully finished the complete course of the Electrotechnical Department, during his stay at the Academy he worked out on

his own the project of a radar station for the Black Sea and a ship direction-finder, and carried out experimental studies of the regenerative set for distance control." He concentrated now on his teaching duties and was preparing his students for graduation. It so happened that his students were graduating several months after the graduation of their instructor. And if earlier, at the Higher Naval Engineering College, there were only a small group of students of radio, now for the first time, with the help of Berg, a radiotechnical department was organized. Later on a special Higher Naval College of Communications and a retraining course for communications officers were instituted, and in 1926 Berg became their Acting Chief.

The College was housed at the Admiralty, which had no radio base whatsoever, and students, under the guidance of Berg (just as several years earlier Berg and some of his colleagues under the guidance of Fraiman), got down to organizing radio laboratories and rooms.

It would be of interest to have a look at Berg in his new capacity. But it would be quite a task to find our hero in the huge, mile-long house of the Admiralty on the bank of the Neva River. True, the spire of the Admiralty seen nearly from any place in Leningrad could serve to us as a good reference point, and we would find Berg somewhere, if not in a laboratory, then on the roof. The roof of the Admiralty provided excellent services for the restless tribe of the radiomen who were inhabiting the building. The roof was decorated with many a bizarre structure in a wild assortment of shapes, for example, a fisherman's net and open-work cylinders. The variety of shapes and types of aerials tested by Berg during his investigations of underwater communications on the Neva defied all imagination. Once he even contrived to "stick" his aerial for radio communication with Kronshtadt into the bronze bodies of dolphins installed at the top of the Admiralty wing near the Palace Bridge. That lack of respect for architectural values infuriated the City Architectural Board, and the aerial was urgently removed and transferred to another place. And even if we would be lucky to get a glimpse of Berg and his students manhandling the aerial or mounting it, we would hardly gather some solid impression, because almost anything was being done in a rush, without words. The students, called by a bell, rushed to lecture halls, and their leader,

in the same pace, bolted for the Naval Academy. (There, pending the outfitting of the labs at the College, Berg was carrying on with his research.)

Having stormed into the laboratory, Berg would attack the head of the laboratory Vladimir Kazansky with his suggestions. He was spending many days, and even nights, with Vladimir drudging at new radio valves. In addition to the anode and cathode, they managed to place into them two more electrodes, two grids, in the hope to improve the efficiency. Nobody understood then the physical essence of the phenomena occurring under the glass bulb—Berg and Kazansky decided to find out experimentally what might be expected from those innovations.

Two-grid valves attracted the attention of radio workers by their unaccountable problems, which made it impossible to realize their obvious advantages. In the bulb of a three-electrode valve—a one-grid valve—the electrons emitted by the hot cathode make their way to the anode through the grid, which sort of accelerates them and controls their flow. Engineers naturally decided that by introducing a second grid they could improve the amplification provided by the valve and make it work with a lower voltage than the three-electrode valves. It was thus hoped to boost the power of the transmitting stations, for one thing, and to have receiving stations to receive weaker waves, for the other. And there is hardly a more burning issue in radio. Several articles appeared on experiments with novel valves, but neither of the models went beyond the laboratory stage.

"Why? Perhaps things only seem to be apparent?" wondered Berg and Kazansky." Could it be that different pieces of valves as received vary widely, and therefore for most of them a standard regime appears to be non-optimal?"

The situation was complicated by the fact that the theory worked out for one-grid valves failed when a second grid was introduced. The famous Langmuir equation, which was the staple of young electronics, jibbed here. There was another universal aid, the so-called "equivalent potential", which helped to compare identical phenomena. But there being no true equivalence between valves, the method led to false conclusions.

If theory was helpless, decided Berg and Kazansky, the only path that remained was experimental studies. But here

too they did not expect an easy triumth. The first snag was the absence of suitable measuring devices.

They needed precision measurements of tiny voltages, and they wanted a device to measure voltage (voltmeter) that would not absorb an appreciable amount of energy, otherwise its readings would be inaccurate. And all the devices available at that time drew some energy, of course. The experimentalists were in need of a special voltmeter, and they even visualized in general the necessary device, but they could only dream of a ready-made voltmeter of that type.

They decided to manufacture it on their own. If even factories were not producing such devices, one can only imagine the difficulties with which they faced.

Berg and Kazansky tested six circuits of valve voltmeters available in the journals—to no avail. But stubborn work bore its fruit. Disputes and trials begot a seventh version. A novel circuit. All of its elements were familiar as words in a native tongue. But it is not given to everybody to find combinations of words that make them poetry.

Berg wrote in his report: "An ordinary three-electrode valve, a simple transformer included into the circuit of its anode, a microammeter switched to the secondary winding of the transformer together with a crystal, and the problem is solved. One has only to install the spring of the crystal at the 'crude' point, not to hunt for the maximal sensitivity. Under these conditions the voltmeter works in a very stable way for hours. One must also be careful that the working point of the valve characteristic be constant." And much of that Berg had already grasped during his nightly torments on the E-8.

On 21 February 1926 Berg submitted to a journal an article, in which he, drawing on a considerable body of evidence represented in the form of clear graphs, maintained that two-grid valves are superior to one-grid valves only under low loads. That article saved time for hundreds of radio engineers by eliminating false paths.

Berg selected the most authoritative radio journal of the time, *Wireless telegraphy and telephony*, still in existence today. And the article, illustrating the creative handwriting of Berg-scientist was accepted by the exacting board for publication.

In those days, filled to the brim with scientific work,

Berg could be met near the Admiralty or Naval Academy at any time of the day and night.

Two o'clock in the night. It is quite light—the northern June. Trotter-driven carts dash along streets. The year is 1926, the new economic policy (NEP) is in full swing. The merry-making dressed-up public are riding to the islands or to the Summer Garden. At the entrance to the Admiralty appears a man with a tired face—Berg returns from the laboratory. He holds a thin folder. This is the result of three months of arduous labours. He hurries home to grasp some sleep, to take a shower and once more to collect his thoughts, so that in a dark civilian suit, later in the day, to appear before the higher "senate" of radio specialists at a meeting of the Leningrad Society of Radio Engineers.

We would hardly understand much from that report. The minutes carry its name, "Theoretical and experimental studies of grid detection", and note that the report evoked a vivid discussion and aroused great interest. Interest in a question that was by no means new? It is strange: detection at that time was well-known and could not attract much attention. Everything in it seemed to be fairly simple. That was the past stage of radio engineering. Suffice it to take any three-electrode valve, nearly any capacitor and a resistor, and your valve detector is ready. Selection of the rated parameters of the capacitors and resistors is so simple that hardly any more sophisticated theory was needed.

"And it is bad," said Berg, "we have therefore essentially no progress in detection, and at present we do within techniques established a decade ago."

Really, in the Russian literature grid detection was nearly ignored. Foreign publications were not complete and did not enable practical calculations to be made. An exception, perhaps, was the work by Colebruck, which took the author a year and a half to accomplish and which was published when Berg had essentially finished his investigations. For the most part Berg's studies had been carried out at the new laboratory of the Naval Engineering College and only some measurements had been performed in the Academy's lab, which was outfitted better.

The seemingly simple process of detecting, easily realizable by any radio amateur, on closer consideration turned out to be not that simple at all. It defied the traditional

mathematical treatment. Berg had been attacking the problem using all the arms available in his armamentarium. When he consulted mathematicians they only spread their hands.

As is so often in science, the answer came quite unexpectedly, when Berg with his students was conducting practical studies on ships of the Baltic Fleet. He remembered his first maritime speciality, the tiresome course plotting.

A navigator is only applying simplest formulas. The most difficult part of his calculations is done graphically, using a pair of compasses and a rule.

Berg locked himself in his cabin. By the morning the main landmarks were marked out. It was possible and necessary to combine graphical methods with calculus and differential equations.

The rest was a matter of skill and perserverance. The specific problem of grid detection was a straightforward exercise. But the audience and the readers of his article were interested not just in specific results but in the potentialities of the new semigraphical method. A method that was later splendidly developed by Berg and that was to become one of the main techniques of present-day electronics.

To Sparkle the Thought!

One work after another, a whole succession of first-class pioneering contributions... Berg was then armed with theory, his head was full of ideas, and he knew the ropes. And he was then not alone, he was always surrounded by his students, similar enthusiasts, real stalwarts. He liked to teach and to guide. He would teach many years and assured that there is nothing more exciting and rewarding: students are like firewood, just bring flame up and they will catch fire. They only have to be enthralled, to be carried away, to be given real business, worthy one's lifetime.

To speak to the audience became Berg's passion. On the rostrum he glew with inner fire of eloquence, and created some magic field around him, the field of sympathy and charm, which invariably infested his listeners with passion.

He developed the ability to come into close contact with the audience from his adolescent years.

Berg related: "For the first time I addressed my comrades at the naval corps. The teacher of naval strategy gave me the assignment to write an essay about the battle in the Straits of Korea and to make a report to my mates. That was in 1912, I was in the third (junior garde-marine) company of the corps, and I was 18, but I still remember the excitement I experienced when preparing this report. I slept little during several nights and read all that I could only lay my hand on, and I planned my report in one form or another. I was all fire, as if I had a fever.

"My second appearance was before the officers and men of the battleship *Tsesarevich.* I was commissioned to make a report about Germany, in 1914. The report was a responsible assignment. It was another fit of fever. And later, in 1922, being already a captain of the *Zmeya,* I delivered a report on the submarine base *Smolny* entitled 'How German submarine fleet was defeated in the war of 1914-1918'."

Then followed the lecture "Modern means of antisubmarine warfare" for the crew of the cruiser *Komintern.* In 1923 the emboldened student appears with his report "On experiments concerned with underwater radio communication" at the Naval Scientific Society before an audience of radio specialists of the navy... Why should these reports be mentioned? Berg in his lifetime made hundreds of reports a year, but then nobody was surprised; the lecturer was an Academician and admiral, made wise by experience and grey with age.

"Why such important reports were entrusted to a young officer it is hard to judge. But I was listened to attentively not only by sailors, but also by older, more experienced officers and commanders."

A good beginning is half the battle. Berg liked the speaker's platform for life.

One of his former students reminisced:

"Aksel Berg was lecturing vividly, excitedly, with temperament, but he avoided a consecutive exposition of the entire course. He normally concentrated on what lied beyond the scope of textbooks, and offered his listeners to go over the missing parts using the literature sources. But he gave a consistent, systematic and clear treatment to novel issues.

"In his work as an instructor he drew extensively on the experience of his best teachers and gradually worked out his own method relying on the absolute contact with the audience, on systematically updating a course with the latest evidence at the expense of relentless exclusion of what has already been recorded in textbooks."

The long-term colleague of Berg, I. Brenev, related: "Early in the 1930s in our higher education were popular a variety of teaching systems, which were called either brigade-laboratory, or group, or Dalton-plan methods, or whatever. Aksel Berg treated these methods with reserve, maintaining that his method always followed the prevailing trend. In that judgement was a measure of truth, because each of the above-mentioned methods as a rule stressed (exaggerated) one or another of the aspects of the normal educational process, which always includes lectures, laboratory classes, and independent work of students, both individual and team. Since Berg combined a wide variety of instructive forms, he could easily bring out and stress in his work that aspect which was at that particular time regarded as a perfect one."

Berg's educational abilities were quickly noted. In a year's time after his graduation at the Naval Academy he was invited as a part time professor to the Military Engineering Academy and the V. I. Ulyanov (Lenin) Leningrad Electrotechnical Institute. In the institute he worked as a professor and head of a chair till 1942.

Perhaps not every educationalist can boast of having his former students always keep in touch with him. With their successes or failures his disciples would later come to him from whatever town they were living in at that time. Among them were Academicians and young researchers. Relations were so close because they learned from him not just dry scientific precepts but also enthusiasm. And also because he could see trees for the wood, and understand each student, each personality.

Teaching went side by side with the scientific activity, he would return to instruction in his declining years. But not just to lecturing, he never gave it up. He would return to the essentials of it, so that to reform the entire pedagogical process on the basis of advanced mathematics, physics, psychology, cybernetics, and to guide a revolution in teaching—programmed instruction.

A First "Crazy" Idea

Berg had hardly read his first course of lectures in his new capacity of a teacher of the Higher Naval Engineering College, when at the end of 1926 the People's Commissar for the Navy instituted a commission to work out a policy of radiofication of the navy. And Berg was appointed its chairman. The aims and purposes of the commission were fairly modest: to make an inventory of the radio equipment available on the ships of war and to produce recommendations as to replenishments. Better than anybody else Berg knew that the navy was outfitted with dated radio stations and that there existed no overall programme of radiofication of the navy. Each naval architect, each signal officer used his own judgement. And the judgement, as we have seen, could not be at the time at a high technical level—radio was still in its infancy and skilled radiomen could be counted on the fingers of one's hand. And one could hardly expect each ship to have adequate radio equipment.

The 34-year-old Berg, who in 1927 was at the head of the modernization of the navy in terms of radio communications, suggested that the entire navy be supplied with modern equipment. Not brand-new physically, but new in principle.

Berg suggested namely that new naval radio stations be based not only on the up-to-the-minute advances in science and technology, but differ from those of the army and aviation; naval stations must be powerful, reliable, able to function in high humidity and vibration, and so on. The main idea was that they must be strictly specialized and standardized. Just as nuts and bolts. Since time immemorial nuts and bolts have been produced in strict accordance with a standard stipulating a range of nut-bolt pairs.

Such pairs are interchangeable, cheap, accessible, and reliable. A similar system, based on specialized transmitter-receiver pairs, had been worked out by Berg. He suggested to manufacture radio stations of several types designed for certain powers and frequencies. In Berg's opinion, this would improve the reliability of radio communication, make interchangeable ship stations, components and valves, and make them more convenient in operation.

The idea of initiating a long-term radiofication programme was supported by such scientists of world renown as

Mints, Shuleikin, Volynkin, and Zilitinkevich. The system was one of the first systems of socialist planning.

The suggestion stirred the entire navy. Some liked it very much, others were suspicious of it. Much heated disputes followed. At the decisive council at the Commissar's the disputes reached their culmination. Some commanders came out against Berg's suggestion to equip the navy with other stations than the army. They viewed this as wasting of funds and failed to understand the advantages of specialization. After all, what could be expected from a green graduate of an Academy? Was there any scientific foundation behind his suggestions? Were they technically purposeful? Perhaps... But not suited to the needs of the moment. No, Berg clearly suggested a harmful policy. The Soviet country was not rich enough to provide specialized equipment for the navy, army and aviation.

What could Berg answer to the commanders? Perhaps, that he was a naval officer and saw every flaw in the navy, felt each its nerve, knew each of its needs; that he was a veteran of two wars on the sea and knew that without reliable communications in a modern warfare the navy was doomed; that only by drawing lessons from the mistakes of the past could one avoid them in the future war.

Who knows what the outcome of the argument would be if it were not for Tukhachevsky, the foremost Soviet military commander.

At the time Tikhachevsky was the soul of the budding telecontrol in warfare. He was the first to pay attention to the Nirenberg's suggestion to build radio-controlled airplanes, and he was keeping an eye on those developments and responded to progressive ideas. He backed Berg full-heartedly.

Acceleration

At that Military Council, where Berg reported his radio modernization programme for the navy and where he was backed by Tukhachevsky, Voroshilov, Egorov and other members of the Council, the programme was approved. Berg was put at the head of the effort, in May 1927 he was appointed the Chairman of Radio Communications and Radio Navigation Section of the Scientific and Technical Committee of the Navy.

For Berg the situation was delicate. He came to occupy the post of his teacher. But that was in the interests of the cause. Fraiman, who at that time was often and seriously ill, understood the situation better than anybody else and provided all manner of support to his disciple. In a year Fraiman died. Berg took over his teaching duties. Before long the Scientific Council of the Electrotechnical Institute elected Berg professor at the chair previously headed by Fraiman.

Despite his enormous load, Berg set out to realize the long-term programme to equip each ship, each submarine and each shore station with radio stations, radio direction-finders, and then hydroacoustic equipment. The programme did not come down to shipments and installation of material. What was to be mounted on ships at first only existed in the imagination of several people. It was necessary to design the apparatus, to make prototypes, to test them, and to start mass production at factories. Factories, which also were nonexistent, were to be supplied with components and valves, nonexistent too.

To cut a long story short, it was necessary to create radio industry.

The effort started off with what was already in existence. New cadre were trained, new shops were added, old shops were modernized, technological processes were improved. In that way started an industry capable of manufacturing those specific types of radio systems which had been suggested by Berg and designed under his guidance.

Step by step, an entire radio industry was emerging to replace tiny plants and laboratories. A radio industry to supply the navy, aviation and army. A radio industry to supply radio broadcasting and civilian communications.

Soon Berg suggested to organize a communications test ground. In 1928 the ground was established, and in 1932 it became a research institute. Berg was appointed its director. The Institute was developing for the navy models of radio and hydroacoustical means, telemechanical devices, wire communication systems and systems using ultrashort and infrared radiation.

Scientific justification of the early naval radio systems was nearly completely carried out by Berg. His publications from this time are "On the selection of wavelengths for ship radio stations", "Selection of power of ship radio

stations", "Radio communications at submerged submarines" and others. These are fundamental investigations related to that specifically practical issue.

The first scheme of radio modernization was put into practice in 1934. Four types of radio transmitters from 50 watt to 7.5 kilowatt were produced. Unlike the old long-wave stations, the new ones used medium waves from 250 to 1900 metres. Having taken due account of the specific conditions on ships and submarines, designers provided convenient selection of ranges, change from transmission to reception and vice versa, stable operation under high humidity and vibration, screening from noise and interference, and many other features.

Suitable types of stations were installed on various classes of ships. Also, the number of station types was reduced due to the maximal standardization of units and components.

Simultaneously, Berg was introducing new ultrasonic equipment, which is kindred in many respects to radio equipment but uses acoustic waves. Unlike radiowaves, acoustic and supersonic waves propagate well in the water and, therefore, can be used to spot submarines, to communicate with them, to control torpedoes and mines. The list of scientific publications of Berg in those years was actively supplemented by research investigations into hydroacoustics needed for development of supersonic systems of communication and detection.

For the naval radio effort Berg and some of his colleagues were rewarded in 1933 with the Red Star Order, new at that time. That was the first recognition of the contribution of the radiomen. And although later in his life Berg would be rewarded with many orders and medals, that first order, number 84, was the most valuable one for him. Perhaps because it was the first or perhaps because Berg was young and has not yet met with real sorrows, which would be no fewer than triumphs.

The list of scientific works of Berg confirms that the reward coincided with a fresh impetus in his scientific output. It was at that time that his classic theory of the valve generator was produced, it lied at the heart of practical circuit design. Then came the theory and calculation technique of the anode, and later grid, modulations, and the theory of amplification of modulated signals. All that Gargantuan

work took only about three years. Three years filled to the limit with directorship of a large research institute and intensive teaching activity.

Since my student years I have on my bookshelf Berg's works devoted to practical design of high-frequency valve generators and transmitters. Among them are also the first three textbooks from the Academy period of Berg's life. His later books are *Theory and Design of Valve Generators* (1932), *Independent Excitation of Sustained Oscillations* (1935), *Lectures on the Theory of Self-Excitation and Stabilization* (1935), and many articles. Specialists know that these are the gold fund of radio design.

The preface to his *Collected Works* issued in 1964 says: "These works of Berg were an epoch in the theory and design of valve generators. His findings were elaborated in studies of other authors and are widely used in practical calculations of radio transmitters. The efficiency, simplicity and accuracy of Berg's methods, applicable essentially to all the regimes of the generator, modulator and amplifier valves, contributed to the development of radio and formed the foundation of the course of radio transmitting devices. It would be exceedingly difficult for a bibliographer to list all the numerous texts, books, manuals and articles on radio transmitters that to some degree or other draw on Berg's works."

The last article of that period, dated 1937, is a comprehensive analysis of the valve generator under any conditions. The method is suitable not only for valve generators but also for frequency multipliers and modulators, and it is valid both for triodes and for the then new four-electrode valves. So Berg's techniques have paved the way for mass production of a wide variety of radio equipment.

Life was moving fast. After the first system Berg developed a second one, which used widely the short wave and even ultrashort wave ranges. By that time scientists no longer viewed short waves as an exotic part of the radio spectrum. But that range turned out to be not without its freaks and called for especial attention and especial approach to apparatus design. Berg was already at the head of a large team of experts, and the second scheme of naval radio modernization was a result of team work.

His friends do not remember when he was at home, when he took a rest. His energies rubbed off on his collea-

gues. He was like an actor on the stage; nobody saw his strains, it seemed as if everything was rolling on its own, easily and merrily.

The documents of the time strike by the fact that they have little evidence of his private life. Many photographs: new laboratories, new devices, glimpses of decisive experiments.

But, what kind of a picture is this? It is like a purple poppy on a green bed, it catches one's eye and attracts attention.

Divorce and Catastrophe

The year is 1924, and the picture shows three persons. A man and two women.

He is in naval uniform—white peaked cap, white trousers, white collar showing from beneath a dark jacket. This is Berg. To his side is Nora, she is even more beautiful than before, in her dazzlingly white, quite modern frock, with a thin helpless waist-band and low neck, on her head a wide band down to the eyes. Yes, she is more beautiful than before and she is more sorrowful than before. Between Nora and Aksel smiles a petite, young woman: a part in the middle and curls at the end of short dark hair. She is also in white, she is also pretty, but she and the whole picture emanate something disquieting. Perhaps this impression is produced because the group is not a group at all, it lacks general feeling. The ends of Nora's lips are down, the other woman is smiling. No, Nora's face by no means matches the spring exuberant green. If you could separate Nora from her companions, the photograph would spring to life, would be permeated with a common mood. He and she, the spring freshness in the faces and background—that's what makes the composition clear and eloquent.

One cannot help arriving at the only conclusion—Nora is unnecessary here.

That happened in the autumn of 1923, when Professor Fraiman and his younger colleagues travelled to the Black Sea for a new run of their experiments with underwater radio communications and radio control of airplanes and motor torpedo boats. Berg was appointed acting navigator on a cruiser and he had travelled by the route Sebastopol-

Tuapse-Batumi. Once at Tuapse Berg went for a walk in the country and chanced upon a picturesque chappel. It was not closed and derelict, as many others, but the graveyard around it was so overrun with the growth that it became a charmed, God-forgotten dead realm. Quiet singing coming from the church—service was in progress there—only served to intensify the sensation of something extraterrestrial and miraculous. Berg was sitting, listening and taking his ease. A twig cracked nearby, he turned around —a girl was sitting with her arms embracing her knees. They got acquainted. Marianna lived nearby in a small cottage bequested by her father. Father died recently, she lived alone, worked as a typist at the port and also made some money by letting two rooms to holiday-makers or seamen. She was 23, she was slender and adroit, grown up on the seaside, a good swimmer. She had gone through much in her short lifetime and believed in nothing—all her life there was much shooting around, some armed men replaced others: the whites were driven away by the greens, the greens by the Germans, the Germans by some other troops. The Soviet power was slow in establishing there. She had heard gunfire more than the whisper of waves. She wanted to study, to see people and other towns.

But for the time being Berg decided to show her a submarine, and brought her to the port. Marianna descended into the fascinating house-cigar. And then all those wonderful people, her new acquaintances—the student of the Naval Academy Berg and his companions—went to her place for tea.

No, that was not a fleeting acquaintance. Several years Marianna and Berg corresponded with each other, and in 1924 Nora and Berg came to Marianna at Tuapse and stayed at her place for several weeks. It was at that time that the photograph was taken, for memory.

And then again several years of correspondence, and the Bergs were inviting Marianna to come to them for a while, and if she liked, to stay for good. In 1927 she sold her cottage and went to Leningrad. She rented a room and joined a school for adults. It was hard. She had only six forms of education behind her, and all the knowledge she got at school had long ago evaporated and been covered with more recent and tangible impressions of that hectic time. Both Berg and the Betlingks were kind to her. The old folks per-

suaded her to come to live with them, they had a capacious flat, and Aksel and Nora had their own household, on the same Glinka Street, in the same house. It was even livelier for the parents, and besides they started to see more of their daughter and son-in-law. Nora and Marianna became friends, and Berg was snatching a minute now and then to help Marianna in her studies. He responded enthusiastically to her desire to study. She needed him, or perhaps it just seemed to him. Or Berg's head was full of Ibsen and his words sunk into his heart: "Bring me to a high mountain and show me the world and all its grandeur."

Marianna did need him. Nora never needed him. On the contrary, she endowed him with the richness of her personality, her formidable erudition. She was splendidly educated, she, and her architect sister, and all the Betlingks were generously endowed with a wide scope of interests and a bit spoiled by the refined milieu in which they mixed, they seemed to be absorbing culture just in passing. Berg was always a shade uneasy in their company—say what you like, a boarding school could not give what home education could do in families like the Betlingks. Everything he had achieved in his life was of his own making, he had worked like a horse, indefatigable and oblivious of amusements and rest. And everything had come to him the hard way, only through his persistence and enormous effort. He had always desired to study and reach the acme of science. He had desired and he made it.

And here was a young girl, without family but craving to get on in the world. He understood this and this tallied with his philosophy: when there is a will there is a way. Berg pictured himself a Pygmalion.

At first everything went as on wheels. In two years she finished a secondary school and joined the preparatory course for the Electrotechnical Institute. In 1928 she passed all the entrance exams and entered the Institute. The same institute where Berg taught and where the next year he was elected professor and, on Fraiman's death, head of the chair of radio engineering. Berg was happy.

In his life, the life of a man for whom science was the be-all and end-all, emerged the state of amazing harmony. His thought, which since small hours was focused on most complex problems that were in profusion as the naval ra-

dio modernization programme gained momentum, failed to switch over in the evenings to artistic spheres and be distracted by wordly chats in bohemian salons, a by-product of the new economic policy.

Evenings were now devoted to higher mathematics, mechanics and electrical engineering, which his new charge was mastering, not without difficulties.

Solitude *à deux* in a large, quiet flat...

Rundolf Betlingk was not entertaining guests any more. Obviously, the old age was telling, and his old friends mostly dispersed, and new ones did not come. His medical colleagues mostly talked shop. The time of home concerts had gone. Now the doctor preferred to spend his evenings in the philarmonic hall or, accompanied by Nora, went to the opera.

Nora, too, was rarely at home. Some of her colleagues in her design shop were real artists, having good studios. They devoted their day hours to the service only because their art, which was not much in harmony with that eventful time, could not support their families.

In the evenings Nora was painting in some studio. She felt that husband became more and more estranged. Arts became her consolation. Creative work absorbed her spiritual fire, gave her firm ground under her feet. Tired and reconciled, she returned to her sleeping home, free of any family chores, to leave for her work first thing in the morning, and then again to her favourite water colours, painting, porcelain.

Such was the life of that family now.

Maybe some reader awaits a melodrama or tragedy, but everything worked out in a way I have never encountered in life or novels. And since my imagination defied me, I approached Berg.

"In what capacity were you receiving Marianna in the house of your wife?"

"Just came a girl. A good girl, who wanted to fight her way to the top. She had good makings. I should rather say very good. A girl of principle, she had seen unbelievable poverty, had no connections, was alone in the world and lost everybody."

"And how did the Betlingks react to the fact that for this girl you had left their daughter?"

"As a matter of fact, that was done with a general consensus. Everybody got used to her, and so did I. And Nora. At a family council it was decided that we should have to part with Nora."

I meant this when I said that. I've seen nothing of the sort in my life. Neither that sort of people nor that sort of decisions.

The history had its beginnings in older days. In tracing them we would have to revert to the time when Nora and Aksel, nearly children, met and loved each other. Had they time to love really, understand and accept each other? The freshness of the first feeling had gone, and what then? War! Could one regard their life marital, if they had not spent together a month at a stretch? And were they to blame that their feelings had not strengthened, matured, nor even taken shape in a real manner? The wars had smashed their young years, they had made no real family, had no children. And Berg was dreaming of a baby, and so was Nora.

But fate decided otherwise. In Nora's life also appeared a man, so much unlike her husband. Not that much devoted to work, absolutely foreign to science, and in some way close to the artistic nature of Nora. Elmar Kolang, the chief of the design office where Nora worked, a tall handsome man, an artist, a sportsman, a socialite. They had been going out together since 1926. All the four angles of that unusual geometric figure were on the best of terms with one another.

Late in 1928 Aksel and Nora divorced. Soon Marianna became his wife, and next year she gave birth to a daughter.

Nora remained his friend. She pursuaded Berg to stay with his new wife at her flat, and moved to her old folks, to her old maiden room. She was still helping and supporting Marianna. She visited them, sometimes stayed over nights, tried to reduce frictions. Urged Sasha to come to live with them and to take care of the household and the upbringing of tiny Marina.

Berg, in turn, was backing Nora financially all her life. Their relations remained warm for life. Her family life turned out to be a failure. Kolang contracted tuberculosis and died soon.

The end of the Betlingk family started with the death of the doctor. Rudolf Betlingk had a stroke, and for several years he had been confined to bed, nearly motionless, nearly unconscious, more dead than alive. In 1937 he died. In a week suddenly died the husband of Dagmara, Nora's elder sister.

The year of the death of the old Betlingk turned out to be nearly fatal for Berg as well.

Second Life

Oh, the memory of the heart! You are stronger
Than the sad memory of the mind!

from **K. Batyushkov**

Chapter One

The Come-Back

Do You Trust Me?

Miracles occur in all times. One of the dawns Berg met at home. True, not in Glinka Street, but... at home, in a small room of the flat of his friend and student B. Mozhevelov.

Marianna stands dumbfounded, with tear-stained face. Nora is all glowing with happiness, Margarita fidgets with the buttons of her overcoat she forgot to take off. Tiny Marinka stares wide-awake at the almost strange man. Elizaveta Berg, Aksel's mother did not live to see her son back. She passed away suddenly two months before his return.

Thousand days had rolled through Berg's life, and each day was torturing his soul and heart. Waves of brain-racking doubts, insoluble questions. Perhaps that was just a dream. Hardly ever before had Berg subjected his life to such a thorough analysis. He knew that there had been a mistake and wanted to find out why the calamity had

struck him, not another man. Could he have given any excuse?

Besides his personal adversities, he was tormented by his concern for the cause, for the fate of the country. It was clear that the Germans were preparing a war. The Party was taking decisive measures to strengthen the country defences.

Would there be enough time for the realization of the naval radio programme; who would continue the development of distant control systems for airplanes, motor boats, and mines? What was going to be the fate of radar? It was just making its appearance, and nevertheless the prospects of that new, unparalleled equipment were obvious.

Berg was concerned with the progress of the work started earlier. Admittedly, there are no irreparable people. But human experience is always unique. What has been accumulated by many years of a scientist's work is invaluable for science and can rarely be repeated by others. Another man may accomplish more but never will he follow the same path. Even during the days of forced idleness Berg had been thinking about better approaches. But whom could he convey his ideas to, how were things at the Institute? News reached him: the work was in progress. It was continued by his associate Ya. Varaksin, now the director of the Institute. Berg was satisfied. Varaksin was a gifted manager, a man of principle and a true friend. He had proved this in need. Another friend of Berg, M. Krupsky, the nephew of Nadezhda Krupskaya, Lenin's wife, also justified his hopes.

And now Berg was back at the Electrotechnical Institute. On the face of it, there was little new here, Berg's laboratory had changed less than he himself. Some friends and workers were absent, but most of them were still there, they were happy to have him back.

Life was taking shape gradually. Never before paid Berg so much time to trifle things—in earlier days he just had no time to notice them. Now he was more often alone and started to write his diary—ideas called for an outlet.

The Sun is Shining Again

"... 2 January 1941. We met the New Year in our old flat. It is again ours. We decorated it anew. Came Misha Krupsky with Tasya, Volodya Siforov with Ekaterina, Serafim

Drobov with Zinaida. Marina sat with us till 2 o'clock in the night. We hung signal lamps instead of candles on the New-Year's tree, it was very beautiful.

"The Naval Academy nominates me for election as a Corresponding Member of the Academy of Sciences. It was decided, on behalf of the head of the department, to send inquiries to radio plants for their response.

"Lectures at the Electrotechnical Institute ceased. Examinations are coming. In November and December I had to work hard on the theory and design of heavy-duty valves, penthodes."

The penthode is one of the strokes of genius in radio sciences. Who is to be credited with its invention? It is quite obvious that several investigators have independently begotten the idea of introducing into a valve a fifth electrode, which has given the name to the valve. This electrode is the third grid, reckoning from the cathode (which emits electrons) to the anode (which attracts them). This grid, having the shape of a loose spiral and charged to a low potential, and normally just connected to the cathode, makes a real valve behave like an ideal tetrode. The tetrode is a valve with two grids. To the first, as usual, the alternative voltage to be amplified is supplied; to the second, a constant voltage. This markedly improves the gain. So states the theory and confirms practice... but only at low voltages. Above a certain limit the valve's behaviour changes in an unusual way. It rebels and will not follow the ideal predicted by the theory. Its responses are distorted. It becomes unpredictable. As the voltage is further increased, the anode current does not grow but drops sharply. "Drooping characteristic" say engineers. "Secondary emission" say physicists. Electrons accelerated by a high voltage hit the anode and knock out other electrons from it, about 10-20 electrons each. Some of them are attracted by the second grid charged positively. This effect is responsible for the reduction in the anode current.

But the third grid of the penthode, lying between the anode and the second grid, with its zero potential throws the secondary electrons back to the anode. And if they all come back, the secondary emission has no influence on the magnitude of the anode current. The "drooping" part of the characteristic disappears, it becomes the characteristic of the tetrode in the absence of secondary emission. The

penthode behaves as an ideal tetrode. Now it is clear to any radio amateur, but then...

"Should we really decline that wonderful finding?" thought Berg.

"...10 January. I keep working on the theory of penthode. During a month I got responses of the plants in connection with my nomination for the Corresponding Membership of the Academy of Sciences. All were positive."

"...15 February. In accordance with my obligation I submitted to the Academy the materials on penthode design. The work produced no response whatsoever, which not only surprised but also offended me—it has been quite a job."

Berg was now so glad to notice the slightest sign of attention to him, each hint of sympathy and each evidence of his reputation being still high.

He was elected to the Bureau of the All-Union Scientific Society of Power Industry... He was invited as an opponent to the defence of a candidate thesis... By an order of the People's Commissar of the Navy he was appointed Editor-in-Chief of a regular textbook on communications for higher educational institutions... He was invited to a Komsomol meeting at the Electrotechnical Institute and elected to the presidium, and he addressed the audience, quite well in the opinion of his comrades...

This all seemed to be so important to him that the details occupied several pages.

These manifestations of attention were necessary to him to strengthen his vitality and self-confidence.

It was so important to know that he was trusted, considered an honest and loyal citizen. He was a man who had suffered from a heavy disease, and was eagerly and hopefully seeking for every hint of recovery.

And his rehabilitation was really pacing by leaps and bounds. In February 1941 the Scientific Council of the Electrotechnical Institute unanimously decided to support the nomination of Berg for Corresponding Membership of the Academy of Sciences of the USSR. In March, by an order of the Commissar of the Navy, he was appointed a member of an expert commission. In that connection he went to Moscow and worked there 10 days. Also in March one of the leading plants notified him that he was included as a permanent member of the Technical Council of the plant. Berg agreed gladly.

On 19 April the newspaper *Red Electrician* of the Electrotechnical Institute published the article "The Grand Life". The article related about the life and career of Berg with great sympathy. It surveyed and appreciated his major scientific works, described his teaching activities and his contribution to the life of the Institute.

The situation at home was not that good. Sister Margarita was seriously ill. She was in a hospital with heavy anemia. Her daughter lived at Berg's. Aksel was worried about his sister, in the last years they warmed especially to each other: they were the two survivals of a large family. His wife cooked specially for her and sat for hours by her bedside. The household was neglected. The girls were of little help, they had a busy time—because they went in for examinations. And Berg was again in his element, he was deep in work, which unfolded vehemently, reaching his customary all-embracing tempo. New programmes were initiated, lectures and seminars were in full swing. A new course—methods of radio acquisition—was being planned.

"I'm working much, but time is scarce all the same. I want to compensate for the time lost and to progress at the fastest pace possible."

And all of a sudden on 22 May: "At about 6 o'clock in the morning I switched on the radio set and immediately heard, quite unexpectedly, that the Council of People's Commissars promoted me to the rank of engineer-rear-admiral. Hurrah! Maryasha was sleeping. She was dreaming about Stalin and me... She awoke perturbed and suddenly heard my name on the radio. A miracle. My photograph appeared in all newspapers.

"All day telephone calls, postmen bring letters and telegrams with congratulations. My friends, it seems, consider the happening another rehabilitation after the undeserved disaster. Interestingly, that was the first order of the Commissariat of Defence signed by the new Commissar of Defence I. V. Stalin. Is this really the end of my ordeals? Is it possible that I may gradually forget my misfortune?"

But only one month was left for rejoicings.

22 June 1941

"...We were taking a stroll with Maryasha in the Botanical Gardens, enjoying a wonderful, sunny weather. We paid

attention to a large number of airplanes overhead—only when we got home we learned that the war started."

The Soviet Union experienced all the dramatism of the formal words "unexpected assault".

All the summer of 1941 the Nazis, as hungry locust had been devouring ever new spaces, and swallowing towns. Disregarding enormous casualties they kept wedging into the Soviet territory, killing, raping, destroying. The map of the Motherland was shuddering and bleeding. Leningrad, which had many times baffled onslaught of the enemy, took up arms again.

Berg was appointed a member of the Commission of the Regional Party Committee for defence works. Together with Academicians N. N. Semenov and A. F. Ioffe he took part in saving the Leningrad industries.

Along the Neva River, along the Mariinskaya system of rivers and canals ships were hurriedly evacuating Leningrad offices, valuable equipment of plants, and, above all, children.

The work in the Commission turned out to be a beginning of a new stage in Berg's life. The task of the Commission included the evaluation of the state of affairs in radar detection of airplanes. They had to establish urgently the status of radar studies at various laboratories, to mobilize radio specialists, to evacuate plants and valuable hardware.

Radar now attracted attention of military commanders. Radar is a special kind of weapon. It does not shoot, does not destroy aircraft and ships. And nevertheless, under the vail of strict secrecy radar investigations were conducted in all the industrially developed countries.

The underlying concept of radar is based on well-known principles. Therefore, it was immaterial who was the first to turn them to practical use. Studies started nearly simultaneously in many places. The point was who would win the race. Who would be successful in putting radar to the services of his state, his army. It all boiled down to who would be the first to manufacture a device capable of determining quickly and accurately the distance to small, fast-moving objects. Radar is spotting using radiowaves. The waves are sent out by an aerial in the form of narrow beams, just like beams of flood lights. Most modern radars beam out radiowaves not continuously, but in short bursts.

On emitting a burst, a radar "waits" for the beam to hit a target, to reflect from it and to come back. Knowing the velocity at which radiowaves propagate (the velocity of light) and the time taken by the beam to cover two legs of the journey, the distance to the target can be readily worked out, and from the angle of slope of the aerial the altitude of the target can be found.

The principle seems to resemble the one on which the sound detector is based. When aircraft started to fly at nights and in clouds, sound detectors were produced that spotted the planes from the noise of their motors. Those were passive devices. They radiated nothing, but like hunters listened keenly to nightly noises. Sound detectors were good, but only when the velocity of planes was below 500 kilometres per hour. Detecting high-speed planes was beyond the capabilities of sound detection. While sound carried to the device, the plane had already run away. And so sound detectors became helpless. Engineers naturally desired to replace sound by some faster means. But which one?

The answer was found much earlier than the question was posed. When Alexander Popov was conducting his experiments in the Gulf of Finland, he noticed that if a ship passed between receiver and transmitter, the reception impaired drastically. Popov understood that some of the radiowaves were reflected from the metal masses of the ship back to the radio transmitter. It was thought possible to apply radio to control the entrances to bays and gulfs, to guard channels.

Popov wrote in one of his reports in 1897: "The utilization of a source of electromagnetic waves on light-houses in addition to light and sound signals might make lighthouses workable in a fog and in a rough weather; a device detecting electromagnetic waves might sound a waving signal about the proximity of a lighthouse, and gaps between the sound signals would make it possible to distinguish between light-houses. The direction of the light-house could be approximately determined using the property of masts, rigging, etc. to hinder an electromagnetic wave, to shadow it, so to speak." But the inventor of radio made no use of his remarkable observation and did not realize his idea.

The concept of using radiowaves to pinpoint sea vessels and other large-size objects matured in parallel with the development of radio engineering. Many patents have been

issued for a wide variety of devices; many constructions have been worked out, including such that cannot be distinguished from present-day radar, that is, active devices beaming out radiowaves and receiving signal reflected from a target. But there was no apparent progress beyond the stage of conceptual design. Radar called for special-purpose valves, special-purpose aerials and special-purpose detectors. But the main requirement here was that for radiowaves to "see" a target and to reflect from it, their length must be far smaller than the size of the target. And the smaller the better. If the wavelength is larger than the size of a target, the wave will easily pass around it and will proceed farther in a manner like sea waves pass piles of a landing stage or small rocks. The sea waves reflect back only from large obstacles. Therefore, for the concept of radar to be viable radiowaves must be short, from several metres to several centimetres. But radio valves available in the early 1920s could not produce so short waves. Their power fell off quickly as the waves became shorter. The difficulties involved were both of fundamental and constructive nature.

In 1920 D. Rozhansky started the investigation into the behaviour of electrons in a magnetic field. At a conference of physicists in Leningrad in 1924 he reported on the possibility of producing superhigh frequency oscillations using those effects. As a consequence, a device was born, which was the heart of a practical radar set, the magnetron. In 1924-1925 by means of the magnetron Soviet workers generated 60-centimetre radiowaves, in a year they were already able to produce 30-centimetre waves, and in 1927, 7.6-centimetre waves, that is, they were the first to venture into the centimetre range. An improved magnetron, suggested in 1929 by M. Bonch-Bruevich, enabled substantially more powerful microwave oscillations to be produced. Now magnetrons could yield waves as short as about a millimetre, and the power of pulses was up to thousands of kilowatts.

Rozhansky proposed in 1932 a new device to generate microwave oscillations. The device came to be known as the klystron. The klystron could give the same short waves as the magnetron. But unlike the magnetron with its fixed frequency, the klystron allowed simple and convenient control of frequency by changing the voltage at an electrode.

The coming of the klystron and magnetron enabled the Soviet radio science to start works on radar as far back as

the early 1930s. The earliest days of Soviet radar are associated with the names of Yu. Korovin, P. Oshenkov, B. Shenbel, and others. Studies were under way at various centres.

In 1935 Yu. Kobzarev, P. Pogorelko, and N. Chernetsov were the first to yield practical results. They produced a pulsed radar station with an oscillographic indicator to detect aircraft. In Britain and the USA similar programmes just started. The prize was so tempting that works were progressing at a crash pace. By the beginning of World War II radars existed both in the Allied countries—the USSR, the USA, and Britain—and in Germany. Germany in 1939 had 6000 radars using 50-centimetre waves. When at Dunkerk, among other British materiél, the Nazis took British radars, they found out that the British stations were rated at 3-4 metres, that is, were less advanced, accurate and "long-sighted" than German ones. Counting on their superiority, the Germans nearly terminated further work on mastering the SW range. As a result they lagged behind hugely. They ceded their positions in the field of SW radar one after another.

But the Allies were making progress. They had derived a good lesson from the early superiority of the Germans in radars: in 1939-1940 in their air raids on Germany they were losing about 12 per cent of their bomber force.

At Toksovo

One of the first Soviet radar stations was installed at Toksovo near Leningrad. On 20-metre masts separated by several hundred metres the transmitting and the receiving aerials were fitted, and in a small house nearby other equipment was installed. The house was also the residence of the workers of the Leningrad Physical Technical Institute of the Academy of Sciences of the USSR, whose director was A. Ioffe.

The Toksovo installation, tested in the Finnish campaign, started functioning at the first air alarm of the Great Patriotic War. True, it was not yet controlling anti-aircraft fire, the coordinates of enemy planes had to be relayed to anti-aircraft command post by telephone, but nevertheless it permitted fairly accurate detection of planes, their distances and altitudes. A skilled operator could even distin-

guish a single plane from a pair, a flight from a squadron.

This installation was demonstrated to the members of the Commission by one of its authors, Yu. Kobzarev, who also belonged to that commission.

Berg climbed up a steep ladder to the aerial for a look-see, and then went down to the operator room. The aerials spinned about their axes beaming out radio pulses, and on the receiver oscilloscope showed a signal reflected from a target. Berg saw such an installation for the first time, although Kobzarev and Berg were looking forward to having such a radar on a submarine long before the war.

The Toksovo radar was one of the pioneering installations in the Soviet Union. One plant had been producing already radar installations called *Redut*. *Reduts* were quite advanced for the day. Unlike the Toksovo system, which had two aerials, the *Redut* had only one, which doubled for reception and transmission. That was quite an achievement, since those portable installations could be moved about on cars with troops. Abroad there only existed a cumbersome two-aerial radar. When a British expert arrived in the USSR, he was amazed. He said: "Oh, we were thinking about a one-aerial radar, but had not dared to realize the idea."

The *Reduts* started to be produced on a wider scale when the plant had been evacuated to Siberia and was quickly deployed on a new site.

With *Reduts* vied two-aerial radio-locators of planes of the type *Rus-2*, by the beginning of the war quite a number of them had been produced. Another research institute developed and manufactured fairly efficient one-aerial radars *Pegmatit* and *Gyuis* designed to zero fighter in on a target. The institute kept manufacturing them during the war after it had been moved to the east. It also started producing radars for gunfire control.

Berg was very much concerned with the state of affairs with radars. Radars were excellent but they were few. Too few to suit the demands. The ideas and novel designs were plenty. Many separate skilled groups were working on radar sets, but there was no powerful radar industry, only few plants existed, programmes were coordinated poorly. What was needed badly was firm management, clear planning, fusing of the contributions of individual groups, design bureaus and institutes.

Berg considered it necessary to intensify the work, but... he had to wait several years.

On 14 August 1941 the Naval Academy was evacuated to Astrakhan.

The professors of the Academy and their families were housed in a boarding-house at Astrakhan. The maximum of comfort possible at the time was provided for the Leningraders. But too much time went on commuting, and Berg soon decided to move to the town, closer to his work. True, the room was inconvenient, small, but he could not afford wasting time on searches. And that was immaterial after all, when everybody understood that it was nothing as compared with what was going on on the fronts.

In December 1941 Japan attacked Pearl-Harbour, and the USA joined the war. The Japanese advanced successfully in the Southern Seas and had an enormous part of the ocean under their control.

Berg greedily pounced on each war report. "We have successes. Rostov and Tikhvin are liberated. Victory at Moscow. The fascists are thrown away from the capital." That was the first war in his life, in which he was not taking part directly. At heart he was blaming himself for staying away from action. Well, he was working in the laboratory, he was training naval commanders for the war, he was sharing his experience with them, the most valuable entity a man can give to another man. But still... He was a veteran of the First World War, was fighting the interventionists, he was accustomed to face the enemy. But now circumstances kept him in the rear. And all the more effort he put into his work, he was preparing a surprise for the enemy, but we will discuss that later...

Letters from his sister Margarita and Sasha were becoming ever more sorrowful. The family was dying in Leningrad. But absolutely impossible to help them. Berg was torturing himself that he had not made them leave the city with him. There was a possibility, and above all it was clear that Leningrad was to meet with a terrible lot; trains were arriving from all over the country to evacuate people from Leningrad. But Nora, her mother, Margarita and Sasha refused to go point blank. They were sure that victory was to come soon and that Leningrad would never be surrendered to the enemy. They all came to live at one place as a family and were ready to survive all the misfortunes. They

were aware that they were to endure unbelievable hardships, but they could not foresee what really happened.

In winter, when the first hungry frosts came, Nora died. How could she survive with her weak heart? Soon another coffin was carried out of the house, with Margarita, and then a third one, with Sasha. The only survivor was Galya, Margarita's daughter.

"... Galya came from Leningrad, dirty, ragged, hungry. All starved to death... How could I have let myself be persuaded. I should have foreseen... Galya was given shelter by the neighbours. She recuperated somewhat with them and set out to us to Astrakhan. Seventeen days the poor girl travelled through all Russia. En route all her belongings were stolen. In June I placed her into a children's sanatorium and she is getting well. The school year is lost and now she will be in the same form with Marina. And how many children are dying in Leningrad, how many victims... The tragedy of that city surpassed all the tragedies known in the history of mankind..."

The Main Trump

"... 15 July 1942. And still life is infernally interesting, and seems to continue so far. There will be much to remember some time. The war goes on. The USA and Britain reached an agreement concerning a second front in Europe against Hitler. We expect this to occur in August, September... So far the Allies sometimes raid successfully German towns. Do we need this? We need our own formidable military power."

Berg was giving much thought to the situation on the front, analyzed war reports and it became absolutely clear to him that it would be extremely difficult to win the war without a sufficient number of radio installations. But without a powerful industry it was impossible to have an adequate number of radar sets. When preparing for his lectures, planning his new textbook, he cherished his new dream: to start works on radar programmes for the navy, army and aviation, and to carry out this programme, like the one after the civil war. If one said "a", it is difficult to him not to say "b". It had not been easy as well, but the navy had been successfully armed with new gear. Berg had been happy about it. Now it was necessary to modernize the

radio equipment of the armed forces. The Germans did not wait, they kept advancing.

"... Radar, radar and once more radar — that is what is needed today. I am especially worried with the situation in the navy. What can we boast of? A *Redut-1* installed early in 1941 on one of the cruisers of the Black-Sea Fleet? The *Rus-1* developed as early as 1939? Several other types of stations, which in their time were quite advanced. But now they are dated."

"There are gifted people and successful designs and beautiful ideas, but the industry is still weak, the volume of work is still inadequate," worried Berg. He had no doubts that a change was imminent, and he had to do everything for victory.

"... I was elected a member of the Court of Honour of the Naval Academy", he recorded on 9 June 1942, "In secret ballot I got 95 per cent of votes. No, life is not over yet. And the radar project—we'll push it through, by all means. This is not only an important and interesting thing, with an immense future, but, in my opinion, the most important trump in modern warfare."

On 19 June 1942, together with Kasyanov, the chief of the communications department, Berg goes to Moscow to the Signal Board of the Navy. Again, he makes use of the trip to attract attention to "radarization" of the navy.

He made reports at the Board, he prepared a draft programme of work on radar and submitted it to Admiral Galler. The draft was audacious, topical and impressive. Berg was offered a number of opportunities: to become chief engineer of the Board of Marine Industries, to become director of a major institute. He was also suggested to collect and restore the Leningrad Electrotechnical Institute, which had lost all its professor and student cadre...

Berg was very much inspired by this all. He saw that he was not forgotten, despite the fact that he lingered on in distant Astrakhan. Undeserved offences gradually sank into the past. He did not mind accepting any of these offers. He was not satisfied with the work at the Academy—the scope of work was not enough for him. He wanted and could give more to the country than he was giving...

War began to be felt in Astrakhan as well. German reconnaisance planes made their first appearance. Once in the daytime window panes shuddered from gunfire. At night another alarm.

"... Several airplanes bombed the railway bridge near the town. This caused a panic. We looked through the window at the street and listened to the whining of splinters. The children were sleeping till 2 a.m. with their clothes on. We prepared some belongings to throw them out in case of fire. However, there were no casualties in town."

Now at Astrakhan alarms and raids were every day. The Germans approached Salsk, at the bend of the Don River. The front was nearing and the workers of the Academy were discussing a possibility of a new evacuation.

The intensified bombings of Astrakhan, the mining of the Volga, the raids on the railway (the only one connecting Astrakhan with Urbakh), the advances of the Nazies to Elista and especially to Stalingrad, this all made it necessary to evacuate or, to use the language of the time, to re-base the Academy in November 1942 to the Central Asia. The transit was a long and uncomfortable one, but all is well that ends well: there were no bombings en route. Having made a long journey via Urbakh, Uralsk, Kzyl-Orda, Tashkent, they at long last arrived at Samarkand. At first the Leningraders lived all together in an office building. Then, after long searches for living quarters, they began to settle down. The Bergs took up residence in two rooms. The rooms were dry and spacious.

"We have beds, one table and one and a half chairs, the other furniture I manufactured out of wooden packing cases," wrote Berg in his diary, "our neighbours are two nurses Lidya and Elena. They are very good and we live in piece and comfort."

Everything was expensive there, but many things could be obtained. The Bergs had taken several kilograms of dry fish with them. This was a great help in their household, and more than that it was an exchange fund. Sometimes they managed to exchange fish for firewood. Firewood was expensive, and took up much money.

The new-comers were fascinated by Samarkand. The European town was good, very green, the streets were lined

up with beautiful shady trees. True, there were clouds of dust, which clogged everything.

"It is late autumn now, but it is still warm. When it is raining, many streets are nearly impassable. Without high gum boots one is lost.

"Maryasha, like in Astrakhan, is a laundress, cook, tailor, and so on. She is a good woman—she bears her cross without a murmur. Besides, she volunteers at a post-office, attends a circle of cutting and sewing and sometimes helps me in my work.

"Marina is doing fine at school, but she is not without drawbacks, with which we are fighting. She was transferred to the sixth form with commendations.

"I've been making Galya burn midnight oil and she has completely made up for the school year lost in Leningrad and went to the seventh form. One of these days she is going out to a farm to pick up cotton, although she is under 14. Both adults and teenagers are doing everything in their power to help the front.

"I have been working much and productively. I am currently preparing a course in power supplies of radio stations, investigating a German transmitter and two new English stations and preparing to read a course in power supplies, which I've never read. I write about 10 pages a day. This is going to be my new course, perhaps, the last one in my life. I want to finish it so much. What I have already written seems to be satisfactory; this undoubtedly is much better than anything I have written in my lifetime. Now I'm free of lectures till January, and I want to accomplish as much as possible in this month. The course comes out good and I work with relish.

"But, frankly, this is not the right thing. Not this should be my occupation. I can hardly read reports from the front—the heart is bleeding. There are no adequate conditions for scientific work here, I haven't got enough scope and cannot display myself. I need self-control, patience, "a hot heart and cool head" as Kasyanov rightly told me yesterday. And I am still too much of a hothead, too impetuous. Although I'll be 50 soon, I have to check myself. Quiet, honest, and painstaking fulfilment of the duty—these are my tasks for the future. And I'll have to think everything over and over again and justify in the theory of radar."

The November of 1942 was clearly a turning-point. On

19 November Soviet troops launched a counter-offensive and started routing the Germans, Italians and Rumanians at Stalingrad. Ninety thousand enemies were lost; 1300 cannons, 500 lorries, 5000 horses were captured.

"May it happen that our successes will encourage the sluggish Allies. A landing in Africa is not a second front. We need a second front in Europe. Leningrad is surrounded, nearly cut off. Attempts to liberate the city fail so far. What other hardships are yet in stock? If only we could deploy the radar effort. Again, I made several reports, and continue to promote radars. We are still using them on all too small a scale."

Chapter Two

In the Forefront

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The Turning Point

The year of 1943 began with triumphs. The German losses at Stalingrad were as follows: 175 000 killed and 137 000 prisoners, and 23 divisions surrounded—the figures amazed the world. The enormous success changed the situation on the fronts drastically. Even the Allies awoke. Italy turned into a volcano about to erupt. What would the year bring us?—asked every man on the globe. Berg also thought about it. He was nearing a serious turning point. This started as follows.

"The chief of the department Kasyanov approached me about my joining the Party. That's marvelous! During my work at the Academy, it seems, I have won respect and confidence. This is good, since I feel a need in the support of the Party. I hesitated, as I was afraid that I would be viewed as if I wanted to climb on to the Party bandwagon. But I always wanted to give all my forces and knowledge to the Motherland and the Party. I want to belong to the Party and in my deep conviction I merit it, but does the Party want it?"

In Berg's opinion a communist is a real man. He knew perfectly well that during the revolution and after it all the true patriots were with the people, they supported the emergence of a new Russia. The best Soviet citizens, together with the Bolsheviks, were constructing a new life, were creating new industries and agriculture, were developing science and culture. Berg was one of them.

"... 1 January 1943. After my talk with Kasyanov, I'm in another mood—as if I'm turning over a new leaf. My folks at home got infected with my joy. Maryasha contrived a cabbage pie, baked a nut cake, and cooked plov from rice and raisins. We met the New Year well, stayed at home, drank wine and listened in. At 12.30 (Samarkand time) Moscow radio reported the outcome of fights from

19 November to 30 December. During this period our troops were advancing and made great strides. The spoils of war are enormous. My soul was singing. Now everyone should give everything in his power for the cause of victory. I join the Party. I've made up my mind. I've written a dozen draft applications and everything seems to be not the thing, inconvincing and arid, and as if not from my soul. Here should be no formalism."

On 7 January Berg at last decided on the following wording of the application:

"During many years I've been striving to be a member of the All-Russian Communist Party. In 1932 I submitted an application, got the recommendations, but an urgent mission prevented me from the joining. In 1937 I again submitted an application, but a slanderous accusation again prevented me from realizing my intention.

"In these days, extremely hard for our Motherland, on my 50th year, after 25 years of service in the Red Navy, I apply for the third time for admission to the Party.

"Despite my social origins (military gentry) I have accepted, it seems, the ideology and aims of the great Party, under whose guidance I have been working all my life to strengthen the defences of our Motherland. The confidence that will be given to me by my admission as a candidate of the Party I will warrant by my self-perfection and my work on the job I will be given."

On 12 April Berg was admitted as a candidate of the Party.

Samarkand Winter

A real northern winter came to Samarkand, and at Berg's there was no firewood and no coal. It was cold and wet. No electricity and kerosene. In the morning temperature dropped down to —18° C. But in the day-time the sun was shining and the snow melted. In the mornings at newsstands long queues of people lined up dancing with cold. Those who got newspapers first were surrounded by people and asked to read aloud. The reports were victorious. The refugees were hectically looking for their home towns in the lists of liberated places.

"... Came the news of the breaching of the siege of Leningrad at Shlisselburg—what happiness! Will we really

go home soon? Our troops are advancing at Veliky Luky, Voronezh, on the Severny Donets River, in the lower reaches of the Don River, south of Stalingrad and in the Northern Caucasus. The army group of 220 000 surrounded at Stalingrad has been liquidated nearly completely. The remains are being destroyed. Now the question presents itself, whether the Germans will have time to escape from the Caucasus or they will get in a mouse-trap there? Why, why then do we not deploy the radar programme? The other day I again made a report at a scientific conference on the issues of friend-or-foe identification and detection using radar. Showed diagrams of identification attachments for radars developed by Genkin and me. As usual got carried away and let my tongue run away with me. But, it seems, I also said something useful."

What is "to deploy the radar programme?" What is "identification using radar"?

At first radar had only one task—ranging using radiowaves. Quite soon it became clear that it was not enough, that radar had much wider potentialities. To deploy the radar programme implied not only to give the front more radar sets and to develop more advanced devices, but also to look for and find new applications of radars. One of the most important challenges became identification.

On 7 December 1941 the US naval base at Pearl-Harbour was unexpectedly attacked by Japanese torpedo-planes and bombers without declaration of war. Pearl-Harbour was protected by a powerful system of radars, and it seemed impossible, to take the base aback. But facts are stubborn things. The Japanese aviation inflicted a tangible loss to the base and the navy. The American military authorities conducted severe investigation. Operators did not deny that they had seen masses of approaching planes on the screens of their radars, but they came to the conclusion that those had been their own aircraft on exercise. And they had serenely waited for that avalanche to approach without informing the Command about the hazard.

Admittedly, the press painted a somewhat different picture, but nonetheless that and other instances of "blindness" of radars posed an important problem before radio experts: to find ways of distinguishing a foe plane from a friendly plane, to solve the problem of identification of a plane or a ship. That was necessary not only for a commander who

controls the course of an air battle, but also for anti-aircraft gunmen who might by mistake shoot down a friendly plane.

That was what Berg meant when he was preparing his report on radar identification. It is worth mentioning here that engineers were quick to come up with an answer to that problem of immense importance under warfare conditions. They suggested installing on ships and planes some devices that incorporated special elements—interrogator and transponder—which were essentially small radio stations with a small range sufficient to determine from a required distance the identity of a plane. The interrogator sent some coded signal, some sort of a pass-word. If the answer was an agreed signal, everything was in order. If there came no answer, that meant a foe. Later engineers provided for many military radars special cathode-ray tubes on which identification signals glowed in other colour than the reflected signals. This improved the reliability of identification and minimized possible errors.

Since the earliest days of the war engineers were raking their heads over another problem. In Allied Air forces circumstances were unfavourable. Many British and American bombers were being lost not in dog-fights with enemy fighters and not due to anti-aircraft fire, but over their own airfields. The cause was the difficulties of take-off and landing. When the number of bombers lost this way became compatible with combat losses, military experts looked into this issue. Everything turned out to be simple and logical. To raise hundreds of aircraft from several airfields at night, sometimes in a fog, and to form wings was quite a problem. To see that this was so a simple arithmetic would do. Let each two minutes a plane take off from an airfield. Hence 30 planes an hour can take off from this airfield carefully, without interfering with others. For the formation to set off for a joint operation the first plane must wait for the last one. To do this, it should circle in the rendezvous zone a whole hour, burning valuable fuel. To expedite matters, they were taking risks by making airborne several planes at once, thus giving rise to crashes.

Home-coming after a raid caused new tragedies. Bombers often returned low on fuel, and they could not be sent out to wait for their turn to land. In the end they had to land anywhere, sometimes absolutely without fuel. As a result

there were a lot of catastrophes in landings on woods, electric transmission lines, fields and pastures, and sometimes on townships.

Air force command got many specialists, including radio men, to tackle the problem. And so, under the pressure of circumstances, the idea was born to use in taking off and landing special-purpose radio systems, in particular radars. The aerial of such a radar, spinning about its axis, sort of scans with a beam the horizon and the space under a plane. The radar is equipped with a cathode-ray tube with a large glowing screen that shows all the objects from which the radiowaves have reflected. And since woods, rivers, earth and structures reflect radiowaves, some stronger others weaker, the screen looks like a kind of geographic map drawn by radiowaves. All the metal things—roofs of houses, railway tracks, etc.—appear in that map brighter than things reflecting radiowaves weakly. Rivers, lakes, seas are dark patches, arable land and forest are slightly lighter. If the radar beam hits a moving object—a car, plane, or ship—the operator can see on the screen its direction and speed and will be able to observe its manoeuvres. Such an all-round looking radar was produced and airmen got a first-class navigating device enabling them to fly following terrestrial landmarks by night, in the fog, or over clouds. Take-off and landing became easier by far—the pilot could see on the screen each of the neighbouring planes both airborne and on the runway.

After the war some confessions were made in the press that early in the war British planes sent out to bomb the towns of Germany not infrequently dropped their bombs on fields and forests, having failed to find the target of their bombing. Simple comouflage and blackout were enough for the planes not to distinguish a military factory from dwelling houses, and often they even could not find the region where their target lay. It had been to till 1943, when radio experts installed all-round looking radars on the planes. After some modification this radar turned out to be also a splendid bomb sight, which enabled targets to be bombed with fair accuracy even when nothing was seen. And so, as many times before, the point was confirmed that a man cannot predict the fate of his creation.

"... The Germans suffer one defeat after another, the balance of air war has swung in the favour of the Allies.

The Germans escape from the Caucasus in panic, the Soviet troops can hardly catch up with them. The Soviet troops approached Kropotkin and Tikhoretskaya. The Stalingrad group has been destroyed almost completely. The Allies stirred: Roosevelt and Churchill were taking council at Casablanca for ten days. The Germans proclaimed total mobilization. The Allies finished conferring with each other and are preparing something, but when, what and where? In any case they, beyond doubt, decided to take action, considering the favourable situation that came about due to the successful assaults of the Soviet Army."

Studies go on at full speed—the Naval Academy was stuffed with young officers and sent the graduates out to the front. Berg managed somehow to do some research despite his enormous amount of lecturing.

"I started studies of new valves in the laboratory. Plotted the characteristics and pulsation. I'm happy that this is possible in the Samarkand conditions." But life is still hard. It is cold, wet, dark. Salary lasts only 10 days, nearly all money goes on firewood and coal. But those are trifling things.

"To-day Sovinformbureau reported that 300 000 troops not 220 000, as reported earlier, were surrounded at Stalingrad. The outcome: all that mass of enemy troops is either destroyed or taken prisoner. Among the prisoners are 16 generals, including the Generalfeldmarschall Paulus, the commander of the group.

"This seems to be one of the greatest victories in the history of wars. The morale in Germany is shattered, they are sounding the alarm. They are threatened by the perspective of a second front.

"At last the Germans are having their gloomy days.

"Today came the news that Belorechenskaya and two places near Krasnodar have been liberated. I think that in ten days' time the Germans will be finished with in the Kuban."

"...3 February 1943. The battle at Stalingrad is over. All the remaining Germans are either destroyed or taken prisoner."

On 23.02.1943 Berg noted:

"Today is the 25th anniversary of the Red Army. A large celebration for all. This is a large celebration also be-

cause the Red Army is on the offensive and is already 50-100 kilometres from the Dnepr River.

"Liberated are Krasnodar and Pavlograd. Fight is going on for Donbass.

"For me its a double celebration:

(a) Ten years ago I got my Red Star order.

(b) Yesterday, 22.03, the chief of the Political Department presented my candidate card to me, and now I'm an equal candidate of the Party."

"All these events were marked by Maryasha with *pelmeni,* pies and good wine. We were together at the solemn meeting of the Academy, and besides I was at the meeting of Samarkand social organizations. Today is my day off. I'll work at home, I'll start preparing for a new report at the Academy, and again about radars."

Alarm

"...11 March 1943. Yesterday at 5 o'clock in the evening came a telegram from Galler with an order on behalf of the People's Commissar to come to Moscow immediately. What for? For how long?"

This worried Berg so much that the above phrases were written in large lettering and underscored.

He asked to send him another telegram, to explain the reasons and the deadline—he might disrupt lectures and cause a gap in his work. He awaited explanations in a state of anxiety. No explanations were given.

"...15 March 1943. So, I'm going. The Deputy People's Commissar has confirmed his order by a telegram, and yesterday, on 14 March, I left Samarkand. I'm travelling with comfort, in an international sleeping car, in a two-birth compartment, spacious and well.

"I took advantage of a stop at Tashkent to call at the Leningrad Electrotechnical Institute. Learned much sad news. Some professors stayed at Essentuki. That's what has come of my Institute. It is dragging on a wretched existence attached to the local Industrial Institute.

"Again in the train. Recall Samarkand, home...

"At Samarkand some of my students came to see me off. Maryasha and Marina came. Maryasha said the remarkable phrase, "How are you going to live without me?" And in fact, how am I going to live without her? I got so used

to her and to her constant, inexhaustible concern about me. I'll miss her badly. And Marina too. Everybody was so cordial, my friends and students seemed to pity sincerely my departure. For me too it is hard to leave them, to discontinue my work, my course, my laboratory...

"Everything now will be in a new way, although it is absolutely unknown how... What a restless life..."

The company in the carriage was quite agreeable, Berg played chess, chatted gaily with his companions. Laughed when he found out that a can of fish had opened in his suit-case and spoiled his underwear. But he was plagued by anxious thoughts: what had life in store for him in Moscow? Maybe a trip abroad, maybe a new appointment, and maybe troubles. Another three days and everything would be in the clear. Only Orenburg was a distraction. For the first time since his early years he saw his home town—snow, cold, the steppe and only the steppe for six days.

...But this all was like a protracted prologue to a yet unclear film, long-drawn-out, glum, monotonous. But now the director pushed action ahead. Frames were flying by, crowding one event onto another. Life hastened the tempo. Events unfolded. And the story started with Berg's arrival in Moscow.

A Sharp Rise

"...23 March 1943. Moscow. Reached Moscow excellently. Came to Galler at once. He hinted at my planned appointment to electrotechnical industry. Said that I should take up lodgings, and later in the day or tomorrow he would have a more detailed talk with me. Thank God, no troubles so far. And this is the main thing. Maryasha's desire came true: I do not go abroad. I stayed comfortably at the hotel of the Central House of the Red Army. I'll have a short rest, unpack my belongings and at 8 o'clock will go to the Board. Sent a cable to Maryasha 'So far only know planned appointment industry negotiations tomorrow'."

But his pluck was affected. He slept poorly. It was still winter outdoors and the room was not heated. He was dreaming of all sorts of rubbish, perhaps in connection with his new appointment. What was in store for him? What was expected of him? Would he be able to switch over to industry? He who had devoted all his life to the navy. Navy

and radio. He had, but weak, connections with industry. Now it was facing enormous difficulties, perhaps. Was it possible to remove them? And he even did not know what sort of difficulties they were.

And, in general, what might be the role of an admiral appointed a manager in industry? How would he be accepted? Well, he was known and respected in the navy. His reputation was good in engineering circles as well. But that was only the reputation of a man of science, a seaman and an organizer, not a factory engineer. He was afraid most of all that this trip might end up in failure, both for the cause and for him. What if he would not be able to cope with the work?

"Now I'll have to gather all my spiritual and physical energies for sizing up the situation and making decisions, so that those who backed me would not be disappointed", he wrote in his note-book at the dawn of 24 March 1943.

What sharp turns life may make! Berg was supposed to be appointed a deputy People's Commissar of Electrical Industry. "Well, so that's it. Never expected. That's all very well, but... I'm a bit scared. Yesterday I visited People's Commissar Kabanov. The talks lasted from 9.15 till 11.30. I visited a deputy People's Commissar of Armaments. He is my student and a good man. At night in the Commissar's car I hardly made my way to the hotel, many times the car was stopped to check night papers, I had none and was only saved by my admiral's ensignia."

Berg now spent days and evenings at the Commissariat. Bit by bit the contours of his functions came out. He was in for a period of Gargantuan work: to master production of new military radio equipment.

The task was huge. He understood that if earlier the naval radiofication scheme had been implemented by an enthusiastic team of workers, several plants and institutes, then the situation had changed. To be solved at a modern level the problem called for a whole industry, large teams, and advanced technology.

The role of science in national economies had changed drastically—new times required from a scientist not only novel ideas but also ability to realize them. Even in time of peace it is often difficult to see one's idea through from conceptual design to realization. These days a scientist had to be not only a first-class generator of ideas but also a

first-class organizer. This was a rare asset but Berg was amply endowed with it; therefore, he was placed at the head of a business of immense importance for the state.

War stressed again and again the powers of radio. Especially of microwave radios, notably radars. Berg was now asked to be in charge of fitting the army with new technology. To this end, he would have first of all to restore ruined factories, to create a new branch of industry. There was demand for new aerials, power supplies, and valves.

That was necessary for radio equipment using not short waves, once the favourite domain of radio enthusiasts of the 1920s, but ultrashort, that is, decimetre and centimetre waves, which had long been considered scientific exoticism.

Situation was complicated by the fact that the radio engineering was a far cry from that of older days. If earlier, during World War I and the 1920-30s, its main concern had been communications, it then became part and parcel of a wide variety of industries and military technology. Its scope was expanding so swiftly that its concerns could only be understood by a man of formidable erudition.

"... Time is spent in a strange way. I get up at 5-6 in the morning, go to bed at 1-2 in the night. Get tired, but endure so far. Later on I'll have to change my ways. I'm exceedingly excited and always remain under enormous stress. This is going to be either a huge success or a total failure.

"Yesterday all day long I was getting acquainted with the staff of the Commissariat. I was given an office, a secretary and a car. But I don't deserve these comforts yet. Step by step I'm getting to know the ropes and I feel already that my life here is not going to be all beer and skittles, since I'm a stranger here and my acquaintance here is meagre. Now I'm being sized up. Some are watching me with utter indifference, others with apprehension. I'm surrounded by the atmosphere of surprise. Many have fears for their future, for their posts. Some cannot understand the meaning of my appearance here: a seaman in a civilian office. But I've already made up my mind: neck or nothing. No other way out."

But he needed help badly: a shoulder to lean on, a hand of a friend. A new, nearly unknown job. But there were no friends there so far.

The work was interesting, he got involved ever more.

Now he was getting into the swing, as in older days, he was ready to rush into a fight, and he could at last put his back into it. But... no, he was keeping his bubbling energies in check, trying to listen more, sizing up the workers, mentally hand-picking a workable team, making his assessments of the forces involved. Just as planning a combat mission. By nights he was poring over books. He had to be invulnerable in everything concerned with his new duties. He snatched time to get acquainted with new machine tools, remembered his old activity—visited laboratories and plants, and sketched diagrams of future radars. Ahead lay another sphere of activities—not a ship, not a submarine, not the chair of a reader—but production. And here his knowledge, his opinions, his erudition had to be impeccable. Otherwise he would be hardly counted with. He would not be able to command.

He wrote:

"Here is my plan: to get to know our customers, their requirements, the needs of the front. To try and reduce the number of types of radio sets, just as I once did when dealing with the radios for the navy. The aim is the same: to improve the reliability and convenience of using the equipment. To get to know the factories and their bottle-necks; to make things shipshape in the Board and to raise the communications industry up to an adequate level. To improve the image and contributions of radio engineering and to convince everybody that it pays off to spend money on it, since the funds will be recovered soon. To promote the navy and its orders, to help seamen. What a splendid work. To establish a radar business, to expand production facilities, to demonstrate the potentialities of radars. This is a grandiose task. It is worth devoting one's lifetime to it. And so, on, into another action."

At last Berg was back in his own element. In lives of people there are ups and downs. A down, which had put Berg out of business for several years, was over. An up was coming.

A Delicate Business

In his time Berg was sure that the navy needed a unified powerful system of radio communications. He stood his ground when attacked by doubting Thomases, put his ideas

into practice, and their realization by the start of the war proved that he was right. Now he was confident that a new scheme was necessary that would embrace all the demands of the front, including radars, and that it was needed not by the navy alone, but also by other forces.

But radars were not just formulas and drawings, theories and concepts, they were also sophisticated hardware, and to start, and even more so to optimize, the mass production of modern radar sets in the 1940s was difficult and expensive and fraught with enormous technological risks.

The war minimized beyond belief the time-lag between the conceptual design, development, testing, and manufacturing.

The task was all the more complicated by the fact that the industry had at the same time to yield more and more guns, planes, tanks and missile projectors.

Berg was one of those who, having passed through World War I and the Civil War, knew first-hand the role of modern armaments, understood the value of radios, had seen them in operation, and had proved their efficiency both theoretically and practically. To be sure, in a small rear town it was difficult to embody the concept that had been besetting him. But now, when he was to be in charge of production of up-to-the-minute armaments, in charge of the new national radar effort, nothing would stop him from bringing his ideas to life. He would accomplish his plans in the pace dictated by the war. He was not to be baffled by the absence of special factories, production facilities, the sceptical attitude to innovations—he had already seen much of that in his lifetime and passed through it during his naval days. That programme had paid off and this one would do so thousand-fold.

He decided to step up his activities before his official appointment. That was audacity, but the audacity of a man of business. He could not afford wasting valuable time.

The first thing that Berg undertook was to collect his team. "People, people are the main thing. Only then will it be possible to work."

He invited specialists from all over the country. He wanted to lean on them, on their experience and knowledge. Those were Kobzarev, Leontovich, Fok, Pistolkors, Schukin, Arkhipov, Vvedensky, Kugushev and others. They were involved in theoretical studies of transmission, propagation

and reception of radiowaves, in building the first Soviet radio plants, in commissioning the first Soviet broadcasting stations. Among them were those who had taken part in the naval radio programme. Berg relied on these people, they could help the country to create a powerful radar industry.

On the other front, he started lobbying for all those concerned with the new industry. This was a subtle, delicate business. The various organizations had to be persuaded that it was up to them to handle some aspects of the new effort.

Factories, which were working round the clock at full capacity straining all their resources, both manpower and technological, to meet the demands of the front, would have to do the impossible, to master new products. Additional funds, components and equipment would have to be relocated. And Berg started an active promotion campaign among directors and officials. He was indefatigable.

He wanted to persuade all and sundry that a new coherent programme was a must. He wanted to make them boost their programmes, although officially he had not yet been appointed and was not empowered to give orders. He only persuaded and agitated. The task was hard and the time was hard. Pushing around was no good. He visited plants, offices and promoted the new radar scheme. Some heard about this for the first time, got enthusiastic and became his allies. He again radiated excitement, restless enthusiasm, which rubbed off on people, just as the playing of a virtuoso musician mesmerizes the audience. He quickly recruited his following. It appeared that his influence was sufficient to bring into motion the machinery of the offices.

"...29 March 1943. Yesterday I worked all day at the Commissariat. In the evening I was received by Kabanov and had an hour's talk with him. I put down the results of my three day's work and my suggestions."

"...Just back from Galler, I told him about my intentions. A good old man. He will help me."

"...In several days I expect my official appointment. Now I'm not afraid of this, since I've understood much already."

Berg was still having little sleep. His working day was exhaustive—12 hours, and loaded unevenly at that. He still got up early and worked into the night. This brought his day to 17-18 hours, only 4-5 hours of sleep. Then he asked to install a bed in his provisional office. Now he lived as if on a ship of war. Lived where he worked. He felt invigorated.

"... Monday, 5.04.43. By 11 o'clock I came to Commissar Kabanov, and reported my plans and observations for 45 minutes. We were talking peacefully and, to use the language of diplomats, in the atmosphere of mutual understanding and reached a measure of agreement. Kabanov understands humour, can laugh and does not argue for argument's sake. He easily lets himself be persuaded by reasonable points, and we, it seems, could get along with him.

"... I want so much to accomplish what I've been planning. The front does not wait. We should be in a hurry. The difficulties are enormous...

"... I don't know, but by the look of things something is fishy about my business, some undercurrents hinder the realization of previous plans. It may well be that this all will work out as a soup bubble and I'll have to return to Samarkand. After all, I haven't fastened myself on anybody!

"In the morning I was at Admiral Galler's. I like his eyes, intelligent and attentive, and at the same time so tired. When you visit him, you become engrossed by some warm feeling, and optimism emerges. Appointment or no appointment, I'll spend my time here not without use and will have a sufficiently complete, clear picture of the goings-on."

He writes on 11 April:

"Yesterday was a quiet day, I was at the Commissariat and left earlier so that to get more sleep. By slow degrees I've been getting the ropes and mark out something. The weather is fine, and I walked from the Red Army House to Arbat and to the Commissariat. I took my time. Yesterday evening I got a card dated 28.03 from Marina, it got through relatively quickly, in 13 days.

"I submitted to the Government a draft in which I expounded the actions I deem necessary to take to swing the radar programme".

Days came and went, but Berg was still waiting for his appointment. The situation became tantalizing. It was nearly a month since he had been at a loose end. Well, he had made something, but his position was becoming ever more false. Everybody knew that the appointment of a new Deputy Commissar was expected. The decision was expected but it did not come. Especially unnerving was the fact that Berg had not the slightest idea of how he was to plan his life, what was to be expected. Was he to stay here or return to Samarkand?

"I am sick at heart. A few lines in the diary seem to relieve my feelings. I slept poorly, worried by the situation at hand: if I am appointed, I'll have to handle a heavy, Gargatuan work; if not, it will be a disgrace. I was thinking, sleepless. And now in the afternoon comes the Scientific Secretary of the Commissariat and says that preparation is in progress to nominate me for Corresponding Membership at the Academy of Science. He asked me to give him my publications, but they are at Samarkand.

"I'd be so happy if I became a Corresponding Member of the Academy of Sciences of the USSR. The first nomination was ruined by the start of the war."

"... 17.04. Yesterday I visited one of the communications institutes and saw that it was working poorly. As usual, I was a bit too blunt but seemed to have stimulated the workers and made them reconsider the state of affairs. I caught cold in the car and I am now feeling unwell. Took some calcexes and decided not to yield to the cold."

"... 18.04. And my business seems to have no progress. Went to the country today and saw interesting equipment. This month in Moscow has considerably widened my horizons. Although at Samarkand we, too, have some interesting programmes, there we are stewing in our own juice. And here, in Moscow, the main life of the country is focused and willy-nilly you get involved in it."

"Evening. Professor Kozyrev has just left. He has stayed two and a half hours. He has been with the Leningrad Electrotechnical Institute in evacuation in the Northern Caucasus and then at Tashkent."

"19.04.43. Yesterday I was doing nothing in particular all day long. I felt it necessary to distract myself from current events. I went to "The Dame of Spades", then to Masquerade". In short, I was having a rest—and do not pity."

Chapter Three

The Complex Channel

The Dead-Lock Is Broken

What course is this unusual history, a history of the relatively recent past, going to take? A history so unlike those that occur around us in everyday life.

Events in Berg's personal life were imminent. The bush telegraph in the Commissariat had it that he was nominated for the title of an Academician! "Well, frankly, I don't claim for it..." This did not amuse him, other things worried him: "well-wishers" were there with their suggestions and predictions. They whispered that in the system of the Commissariat for electrical industry nothing reasonable could be made with radars. It would be better to transfer the entire radio branch of the industry to the Commissariat for aviation industry. And better still to insist on the total isolation of radio industry into a separate Commissariat. Berg did not rush to conclusions, he was looking around and shaping his opinions. He thought that it was immaterial in which system would it develop, any one would do for that matter, the main thing was to provide good management for the programme.

"...Together with the Commissar I was at the tests of new devices", he wrote on 6 May 1943, "Much interesting and necessary, but that is not the maximum we must and can attain. We have a much higher potential, both scientific and technological. The trouble is that in the office there are still many humbugs and deceivers. But wait till I show them what's what!"

"Spring enlivens the hostilities. In Tunis, it is over with the war. The Germans and Italians there are smashed; many prisoners and booty. Escapers are few. Thus, Africa is liberated. The Soviet and Allied aviations are day and night bombing the rears of the enemy. Everybody is still waiting impatiently for a second front in Europe. It seems

that we will have (for the third time) to repulse the onslaughts of the Germans. Everybody is possessed with one feeling: when will this horrible war end at last?"

The May was fading away, and Berg wrote in his diary again and again the same nearly stereotyped phrase "I've been more than two months in Moscow already and so far my appointment has not yet been decided on. I even stopped to show interest in the question. I am concluding a large preparatory work to expand the radar programme. The work is unquestionably important and will come in handy regardless of whether I'll stay or not. This gives me satisfaction. All recognize the usefulness of the work. But how is one to realize it? Radio armaments could be made more effective should more attention be paid to radar sets. What is to be done? It unnerves me sometimes not to see any real outcome of my work and I'm afraid that I'm just wasting my days. So much time in Moscow I see no end of the waiting. The only consolation is to write and receive letters. I'd like to go to the country-side, but what shall I do there alone? It is spring now—a thrust is coming and the return attack of the Germans. The war enters a decisive phase, and the Government cannot afford caring for technical potentialities that may yield results only in a year's time..."

And still Berg stubbornly kept establishing connections with people and institutions. He was understood by many, and many wanted to give him a helping hand.

"Visited Marshal of Artillery N. Voronov. Made a detailed introduction to radars, he showed keen interest and promised to report this all to Stalin. Last night I gave him a draft programme for Stalin. No idea as to what is to be expected. Everybody understands that I'm making a great job with new approaches. I feel that we will bring the Soviet radar equipment to a leading position in the world."

The meeting with Voronov changed much in Berg's life. It marked the beginning of a long-term friendship and cooperation, that lasted till the death of the Marshal early in 1968. It also helped to swing the balance, and end the tantalizing expectations of Berg.

Berg had not touched his diary for a long time. His impetuous character found refuge in frantic work, and so doubts had to retreat. It was only on 26 July 1943 that appears the entry in huge lettering:

"On 4 July I was appointed by Stalin deputy people's commissar for electrical industry.

"I have little sleep; the work is grandiose. I must carry it out in the shortest time possible. To recruit cadre, establish institutes and plants, organize an industry. Things are progressing, although with difficulty, with an all-out opposition of some managers."

Development and manufacture of radars required not only specialists in adequate fields, but also machines, materials and funds. And to get them in those tight-belt days required a great deal of pushing through and proving by real gains on the front. And woe betide to him who fails! This accounted for the sleepless nights, concerns and vehement promotion activities. Berg drafted memoranda to the Government making the case that the funds large enough to have many powerful tanks should be spent on one radar.

And each Commissar, for tank, for aviation and for shipbuilding industries, also wanted to get more funds to be able to supply to the front his "own" armaments. It was only natural. The reason was not narrow-mindedness, but faith in the might of "his" specific armament. And what about radars? They were useful, without doubt, but who could prove that they were more useful than other materiel.

What was more, to construct new plants for new products would have taken too much time, and so many Commissariats were robbed of their facilities, equipment and people. Put to use were even such shops in which they had not the foggiest idea of radio. Personnel was retrained. Even schoolchildren were making their contribution by manually winding transformers and manufacturing simple components. Engineers and workmen were living and having their meals on production premises. The new chief was arguing with Commissariats for each square metre, for each hand, for each engineer.

No wonder, he left much bad feeling in his wake. Alas, there was no other way, sets of modern radio equipment

were to be shipped to the front on schedule to reinforce air defences of towns.

The records discontinue, and only on 7 September we read:

"I expect Marina and Maryasha to depart from Samarkand one of these days. They may leave even today. I feel dreary alone, live in my office. I count days before their arrival, missing them badly."

At long last, on 17 September, Marianna Berg and Marina came to Moscow. The reunion was a happy event. He came at home on Sundays, and sometimes on workdays he poped in for an hour in the evenings, but continued to live in his office.

The goings were slow. Decisions were forced through with enormous pains. Bit by bit a new branch of industry was taking shape, but that was so difficult in the war time!

Situation on the fronts changed sharply. After an all-out fierce German offensive in July the Soviet troops launched a counter-attack throughout the entire front line, from Smolensk to Novorossiisk, and liberated enormous territories up to Kiev. Italy capitulated.

And again, a common joy came side by side with a personal one.

"Today, 29 September 1943, I was elected a Corresponding Member of the Academy of Sciences of the USSR. It is especially pleasant that the vote was unanimous, by all the 24 Academicians of the Department of Technical Sciences. This seems to be a rare thing for the Academy. There is always somebody who votes against. I had to get 19 votes to be elected, and I got all. The election to the Academy seems to be the main achievement of my life. At home they met the news jubilantly. Life is cutting capers—now an outcast, now a Deputy Commissar, and then a Corresponding Member. Work, work, work, but time is short. It is hard, but I have to cope with difficulties. For several months I haven't done any science, even afraid to start, since if I do, I'll neglect my managerial work. I hope that later on I'll be less burdened and then I'll be able to return to my favourite pursuit. Maybe this will occur only in my declining years?"

Science "for himself" was as yet out of the question. Berg was not only a Deputy Commissar but also a Deputy

Chairman of the Council for Radars, headed by G. Malenkov. Reflections about perfect coordination of work on radars led Berg to conclude that it was hardly advisable to concentrate it under one Commissariat. Under such an arrangement it would be impossible, or exceedingly difficult, to affect the "neighbours", other Commissariats. And if Commissariats only cared for their specific armaments and produced radars completely on their own, the radar situation would be beyond control. A common centre was required. So was born the first state coordination organ in the field of radars, the Council for Radars.

At last Berg could array his propaganda forces. He even introduced a seemingly strange post in the Council, a post of an artist. A man of absolutely civilian appearance was sitting on the premises of the Council and drawing posters: a radar in action—it helps to destroy a plane by directing traces of anti-aircraft shells at it; it helps to sink a Nazi ship by homing torpedo-planes and firing major-calibre cannons. Schemes illustrated the principle of the radar. Another poster showed the "bowels" of a bomber, with over a dozen of radio devices. These included radars controlling guns, all-round looking stations for navigators, bombing sights for operation in clouds and by night, devices for accurately determining the altitude functioning on the principle of reflection of radiowaves from the ground, friend-or-foe transducers, devices warning the pilot that his plane has been detected by enemy radars, device indicating that an enemy plane has been attacked from the rear, and, of course, stations for communications with the ground and sister planes.

Berg would roll up some of the posters and go to a Commissariat, institute, or plant.

He managed to find time for making presentations to radio students and workers. His enormous teaching experience allowed him to present simply and clearly all the various aspects of radars and even antiradar measures.

Whatever a novel weapon, sooner or later comes in an antiweapon. The same was the case with the radar. In one of the posters a plane was spreading thin straps, the caption said—a means of blinding a radar. And Berg would tell the following story. The superiority of the Germans early in the Second World War and the massive loss of Allied planes made scientists look for ways of neutralizing enemy

radars. And so, once preparing for a massive raid on Germany a bomber squadron loaded their machines not with bombs but with some secret weapons. The technicians loading the planes were perplexed: the load was light as paper.

The planes took off and made for a specified region. Their hatches opened and... radars of the German air defence kicked up an alarm: the Ruhr basin, the most important industrial region of Germany was being attacked by enormous formations of Allied aviation.

The radars indicated that the unprecedented mission involved tens of thousands of bombers! An unheard of raid. The German command made all the fighter force airborne, but the operators of the radars could not give a clear indication as to where they were most urgently needed. The screens of their radars appeared simply to be cluttered with marks of the enemy planes. The German fighters were rushing about but... could not spot the enemy. All of an hour had passed, the fuel was low, and the German command did not know what was to be done, what British devilry was behind the trick. The strangest thing here was that in that mission Allied bombers were in no rush to shower Ruhr with bombs. Instead they were marking time, doing nothing. While the Nazi heardquarters panicked, the main forces of Allied aviation were approaching Hamburg from the north, absolutely unnoticed. That was one of the most fierce and effective raids. The German losses were enormous, whereas the Allied bombers returned home safely.

Only in the morning the Fascists could find out what sort of show it was. The fields and woods of the Ruhr region were strewed with paper straps covered with a thin layer of aluminium. They were undoubtedly thrown about in the night by Allied planes. And it were those straps that German radar operators mistook for planes. Ever since the Allies always supplied their squadrons with metallized paper straps, which had proved to be such an amazing means of disrupting the German air defences. Although it was common knowledge, there was nothing to be done about it. Metallized straps were normally dispersed by the leading planes. They would so clutter the radar screens that there was absolutely no possibility to discern anything behind that radar "smoke screen". Ever since the losses of the Allied bomber forces decreased several fold.

That was one of the numerous stories about radar. By the end of it Berg normally drifted into a talk about peaceful applications of radars. Peace would descend on earth... Military radars would be supplemented by peaceful ones. All that had been discovered by scientists would find applications in civil aviation, in merchant and fishing fleets, in national economies. Radars would not be scrapped.

They would be guardians of land and sea frontiers. They would be obedient and careful controllers of air traffic, provide reliable guidance for planes in any weather, by day and night, exclude collisions of aircraft with one another, mountains, masts, transmission lines, and so on. And in the distant future, they might replace pilots, drivers and tractor operators. A radar connected to a control system of a ship would carefully bring her along a complicated channel, avoiding collisions with other shipping or icebergs, and in any weather would lead her into any harbour. A radar could become a reliable aide of the surveyor, improving markedly the accuracy of his measurements.

The friend-or-foe identification principle could be modified to be of help in whaling. A tiny radiotracer could be placed, say, in harpoons used by whalers to help the whalership find the killed whale. Special reflectors could be installed on buoys of fishing nets to make them visible to radiowaves.

Radars would also find wide use in meteorology. Centimetre waves can reflect from clouds. A meteorological radar would be able to warn of an approaching thunderstorm front, a squall, or icing. This would enable a pilot or a navigator to get ready for the hazard since the radar had "seen" it tens of kilometres away.

Those dreams of peaceful uses of radars, despite the war, were not without grounds. Back in 1942 Academicians L. Mandelshtam and N. Papaleksi proved the possibility of using radars for measuring the distance from the Earth to the Moon. And as early as before the war first steps were made by quite a peaceful science, radioastronomy. Few understood then that its future outlooks rely on developments in radar. But while some radars were fighting, others were accumulating experience for science. Only a few experts knew of that experience of radar. Only after the war could scientists look at those curious spin-offs of military radar technology.

This happened in 1942. The operators of radar stations on the eastern coast of England sounded the alarm. Several days in succession the screens of their radars got covered at the break of the dawn with some mysterious clutter, which prevented them from detecting enemy aircraft coming from the east. This occurred simultaneously on several widely separated metre-range radars. It was then that in secret reports appeared an indication that the source of the interference lied in the direction of the Sun. Later it was found that the interference had been caused by a large solar spot. This way under the roar of guns radioastronomy was born, and at that time nobody could hear its peaceful voice. Solar spot studies were only resumed after the war, when the observational data of the radar stations were declassified and astronomers got nearly all radar outfit.

Mystery

Time was passing by. Ponderously, smirking, endowing people with new years of age. Days dropped, like dry autumn leaves, and gradually they covered green grass, flowers and spring hopes.

"... 10 November 1943. I'm 50 already. Old age is coming, the sixth decade... An old man in his sixties. Ahead are the gradual decline of vital forces, deseases and death. Perhaps it's high time to give up. But am I really an old man? I look not that old yet, and at heart I'm young too. Now I'm doing a great job, perhaps the greatest in my lifetime, and I must bring home the bacon. To this end, I'll need much energy, health and tenacity. And confidence in my cause. Do I lack any of these? It's hard to me now—I have been charged with a huge programme, and not all those concerned help me, not by a long chalk. Some are even in the way. But I still feel fit to combat obstacles.

"This year literally stakes my all: my reputation, my happiness, my future, the fate of my family. Have I enough energy to "play high"? Yes, beyond doubt, although sometimes I feel desperate. But I collect myself and quickly shake off gloom and apathy. Well, old friend, gather your forces hardened in life struggles, and on we go! to further victories, for my favourite work, for my dear navy, for science, for happiness, for success!"

Gradually Berg came to the conclusion that no admini-

strative posts would allow him to provide an optimal guidance of such a new field as radars. He felt stuffy in his high office. A special research institute was required in which novel ideas could be tested, problems of practical importance be solved, complex projects be realized. It was necessary not only to establish the institute but also to take part in its work. This was the best path, one that had been tested by him back in the 1930s when in a similar situation he organized Naval Institute of Communications.

Whatever the difficulties of the wartime, the Institute was set up.

And so Berg came back, if only partly, to his favourite scientific work, to be even more useful to the cause.

Came 1944. The Bergs met it at home. A small New-Year's tree was alight with electric lamps, it was like in old days, cosy and warm. On Sundays Berg was now resting. Other days (and sometimes nights) he was working. His business was progressing by leaps and bounds, and tangible effects were felt on the fronts. But Berg himself was discontented, dissatisfied.

"At times I am sick at heart, especially in the Commissariat, where I have to win respect and to provide leadership for a new, unknown activity, and during a war at that. My household gradually becomes established, and my folks are getting used to Moscow. Something is wrong with my heart, sometimes I gasp for air. I must go and see a doctor. I have this with me for a long time, but never had such severe attacks. Could it really be that the old intoxication on the submarine tells?"

But there seems to have been other things behind that suppressed mood. Something was taking place during the first month of 1944. All of a sudden appeared a record:

"What would I care for other people's opinion of me, when I am dead? I shall not have to think then. Poor wife and Marina. And besides, let's face it, I'd like to fight. I cannot yield, haven't been brought up that way. I want to live and prove my case."

Maybe a later record would help us to clarify the picture?

"What importance may be attached to 'this', when not an individual human life, but the future of the entire country is at stake? Everyone must forget about one's ambitions, career and other humbug and to buckle to."

Or this one:

"The Chairman of the Council shows no concern for the radar effort. I'm his Deputy, but actually see nothing of him and get no help from him. I seem to hang in mid-air. Am I to blame for this? I don't remember making any mistakes. This enforced isolation does a lot of harm to the cause, and complicates my work enormously. I feel no support and have lost ground. Decisions on radars are being made slowly and realized yet more slowly. But the war goes on, the forces call for radars, and we give not enough. How could they not understand that if we had more radars our losses would be less."

A War of Radars

On the front a fierce war of radars waged. By slow degrees the new equipment had changed the character of warfare, especially on the sea and in the air. The earlier ways of warfare appeared obsolete, it was necessary to find the roots of those changes, to adapt to new conditions and to work out new strategy and tactics. Once by the end of World War I successful operations of German submarines had brought England on the brink of defeat. The same picture occurred at the beginning of World War II. At first England was losing three times more shipping than she could build, and by the end of the war the situation changed drastically: the Allies were commissioning more vessels than they were losing. Not because they boosted their shipbuilding programmes but because radars were developing vehemently. This is confirmed by the figures: out of the 1 174 Nazi submarines 785 were sunk with 36 000 crews. And the lion's share fell on the last stage of the war. At first, when the Allied forces had few radars, German subs would surface at leasure by night and charge their batteries. They were in safety: neither the observers on ships nor aircraft could spot them. The picture changed when the Allied airplanes got radars. This started an all-out hunt for enemy subs. But the success was not to last long. The Nazies set about finding a remedy, and found. They supplied their submarines with receivers of pulses of British aircraft radars. This exposed the hunters and so the "game" could dive before the hunter had time to zero it on the target. Having learned about it the Allies changed the wavelength of their radars and for a while again got the upper hand in

the competition. Their planes again could surprise the German subs, which had no idea of the wavelength change and were helpless game again. The Nazies sounded the alarm and started looking for the causes of their increased losses. On a specially equipped U-boat a team of German physicists and radio men set on a reconnaissance trip. Before they had finished they cracked the nut. The planes were using 10-centimetre radars. The German boffins were quick to twig that changing the wave-length of their receivers was only a tentative measure, a game of hide and seek would start, with alternative success. There was only one outcome—the German underwater craft should not surface at all. An order went to shipyards, and the German U-boats were fitted with ventilation tubes. Now they could suck in fresh air and blow out exhaust gases of their diesels, and hence charge batteries under water. For a radar which was able to spot a sub, the tiny tubes became invisible. For such small-size objects to be recognized, planes would have to approach closer and their radars would have to use yet shorter waves. This was fraught with difficulties of principle. That type of radars called for new valves, new waveguides, new aerials and other things. The Germans again got the upper hand over the Allies.

The next move of the Allies once more changed the course of the naval warfare, and amazingly fast. They came up with a 3-centimetre radar. It was able to see ventilation tubes of the German submarines from 15-20 kilometres. Nazi receivers were blind to the new Allied radars, and once more their underwater craft became sitting ducks for the air force.

The Germans quickly sent out their trouble-shooting submarine for a look-see on site and an answer. It took the Allied aviation only a fortnight to destroy the U-lab. They took prisoner the only survivor, a physicist dealing with propagation of short waves through the water. The Germans fit out another lab, but she, too, was sunk in several days. Not until the end of the war did the Germans find out that their submarine laboratories had been lost due to Allied 3-centimetre radars.

The war between surface navies also progressed with varying success. In neither of the previous wars, vessels had been equipped with such a wealth of fancy radio gimmicks, which made anachronisms of all the good old tricks of tac-

tics and strategy. Long-range ship radars with all-round looking cathode tubes now made it possible to obtain intelligence in any weather, day and night. Captains saw from hundreds of kilometres away shore lines cliffs and icebergs, and all the shippings. Each move of the enemy became known at a distance from which his guns were harmless. And the accuracy of gunfire now became unbelievably higher. Ships were supplied with radars similar to their land counterparts designed for anti-aircraft defence. They controlled ship gunfire. With their help the Allies conducted an unprecedented operation against the German battleship *Scharnhorst*. She was sunk by a first salvo in an Arctic night. Now radars directed amphibious operations. They improved the accuracy and efficiency of attacks, by guiding beaching forces among rocks and shields in a rough weather.

Both sides were frantically inventing new ways of fooling each other's radars. When the aluminium foil trick became common knowledge, other methods were sought, for example jamming. To this end a powerful transmitter was set off at the wavelength of an enemy radar, with the result that its screen was jammed with spurious signals. Against the background of those powerful interference target signals were hopelessly lost. Experts also worked out another deception trick—special-purpose nonreflecting coatings, which absorbed almost all the energy of radar pulses.

This intensive radar war, or rather a competition of knowledge of scientists and designers, and flexibility of industries of the sides, having started long before the war was in progress till its end. Success or failure in that game required not only fresh ideas but also their swift realization on the basis of a powerful scientific and industrial infrastructure. To win meant not just to surpass the enemy but to beat him hollow.

The Soviet Government was well aware of these potentialities of radars and were making adequate decisions to this effect. The concerned tone of Berg's records disappeared gradually.

A Step Higher

"... Yesterday, on 16 March 1944, I visited the Chairman of the Council. We discussed a draft statute of one research institute. I've been working hard lately and I am terribly

exhausted. It's so difficult to swing anything. Yesterday's meeting instilled confidence in successful progress of the work I am in charge of."

"... The situation at the fronts is excellent. Our troops are advancing in the north and south. Leningrad is liberated; that nightmare went down in history. Our troops have already crossed the old frontier and in places approached Poland. But the Allies are only contemplating opening a second front. At home everything is O.K. Marina is growing and becoming a pretty maid. Maryasha is occupied with household chores, she is doing everything herself. We are well fed, and our clothes are gradually brought in order.

"Since Monday I have a community assignment as leader of a circle studying the history of the Party at the Commissariat. The other day I made a report at the Academy of Sciences in connection with the 85th Anniversary of A. S. Popov's birth. The attendance was large. The report, it seems, was good. For the first time I was reading from notes."

Academician Krzhizhanovsky thanked Berg after the report and invited him to repeat it at the House of Unions for a wider audience. Berg wrote:

"That was my first public appearance at the Academy of Sciences. Next year will be 50 years since the invention of radio by Popov. I'm asked to issue a second edition of my book about Popov and to write his biography."

Berg attached much importance to continuity in science, and in particular he had long been interested in the history of radio sciences. His book *A. S. Popov and Invention of Radio* (published in 1935) referred to in the above record was in fact the first work in which the priority of A. S. Popov had been proved conclusively.

The impending fiftieth anniversary of the famous report of Popov stimulated new interest in the history of radio. Berg was one of the initiators of various functions associated with the anniversary. He was a member of a Commission of the Academy of Sciences charged with identification, systematization and publication of appropriate documents.

The Commission, headed by Academician L. I. Mandelshtam, decided to issue a three-volume collection of documents. The first volume was devoted to the prehistory of radio; the second one, to documents and materials concerned with Popov's inventions; and the third one, to the fifty years of radio since. Only the second volume, the most important

one, was issued by the anniversary. The editor of the volume was Berg. He was a founding father of the A. S. Popov All-Union Scientific Society of Radio and Electric Communication, and he was a member of the Organizing Committee of the Society.

The mass media of the world were writing up the belated opening of a second front in Europe. The Allies occupied Rome. On 6 June the combined Allied forces started landing in Northern France. The end of the war was approaching.

On 16 July 1944 Berg wrote in his diary:

"Hitler's affairs are lousy. The other day 58 000 German prisoners of war were led through Moscow. It was broadcasted that there was some discord in the higher ranks of power in Germany and that there was an attempt on Hitler's life. He got burned. The beginning of the end of the madman and scoundrel. The affairs on the fronts gladden infinitely. A huge offensive is in progress in the Brest direction, liberated are Elets, Vilno, Minsk, Baranovichi. Next in turn are Grodno, Kovno, Dvinsk, Brest.

"The Allies occupied Livorno and Ankona and ascent to Normandy."

"... My old dream came true—I've visited Leningrad. The city had suffered enormously. Made a tour of ships of war, was at Kronshtadt—naval radar sets are functioning very well. What an important and useful thing it is. To deploy them more and faster. So much strength and health will this require. Hardly less than during the first radio programme. If only I had more strength."

In a month:

"By decision of the Council of People's Commissars of 25 September I was promoted to the rank of engineer-vice-admiral.

I sat at the telephone and acknowledged congratulations.

"In the evening Misha Krupsky and some other friends came to my place. We had a cosy evening. I was so happy that on that memorable day my closest friends happened to be in Moscow. Maryasha made a prodigious pie, got some red wine and flowers. The flat was decorated beautifully and everything was so festive.

"Now I'm a vice-admiral and can easier deal with army and naval engineers. I was moved by the fact that a chief marshal of aviation, Admiral Galler and others phoned me. All of them are nice to me and seem to be sincerely glad

on my account. Especially happy, of course, are Maryasha and Marina, since they felt that I was a bit sad. Now it would be easier for me to work.

"I'm poring over a report for Stalin. The going is slow, I want to make it as good as possible."

Yet another month passed:

"24 October. I'm dismissed from my duties of the Deputy People's Commissar of Electrical Industry. I'm so happy. Of course, it is hard to part with people to which you've got used to. So much effort and labour went into the modernization of those plants, and establishment of institutes, design bureaus. But concentrating on the Council, I'll have more possibilities to make the overall radar business shipshape, so that the Commissariats will have to count with the Council. The wording of the decision of the Central Committee is as follows: "In connection with the increased volume of work in the Council for radars dismiss the Deputy Chairman of the said Council from his post of the Deputy People's Commissar of Electrical Industry."

"...As yet I'm feeling strange — no direct executive power as it was the case in the Commissariat. The Council is a fairly unusual activity, and I have so far no clear idea of what will come out of it."

"For length of my service I was awarded by a Red Banner Order.

"I intend to prepare several reports on radars. More attention should be given to promotion. Otherwise there will be no young blood, and hence stagnation.

"At home everything is O. K. Marina is studying English and is doing fine. On Sundays we regularly go for a walk for 3-4 hours, in any weather. This is our only sport.

"I'm doing well, I'm glad that I've left the Commissariat. My work became easier and more interesting—I can think more and can exert more influence on other commissariats. My departure from the Commissariat quenched all interest in radars there. I'll have to shake them up a bit."

Between the Lines

Behind the seeming monotony of the narrative unfolds the history of the early days of that problem child, Soviet radars, the history of collisions of the new with the old, some details of that tempestuous time.

The passion and strain that make themselves felt literally in each line of the diary are caused by the atmosphere into which Berg got in the heat of war.

The records were sprinkled with front reports—Berg took pains not to miss Sovinformbureau reports. They formed the subject of many pages. At the beginning, during his Astrakhan and Samarkand days, this was just a vital need of any Soviet citizen, showing keen interest in each episode of the war. And later, when Berg became a helmsman of the Soviet radarship, he watched the reports from an absolutely different angle. He knew where and how many units of new models of radar equipment had been sent. Behind a matter-of-fact listing of liberated towns and villages, behind a simple indication of the number of lost planes and repulsed air-blitzes he saw the keen eye of a radar set. To be sure, in wartime even in your own note-book you may not write about this, you may not discuss this with your wife or your friend.

Even now radio-location and radars have not lost their meaning, and some of their aspects are still surrounded by mystery. But the fact that Berg's records are necessarily incomplete will not detract from our story. After all, we are not going to study the history and principles of radiolocation from a diary. We are only interested in the inner world of the hero of our book, his strong and weak points, we are interested in a man who accomplished what only rare personalities can accomplish. We are excited not only by what he had achieved, but also by how he has achieved it, and by other what's and how's. We are interested in his powers, his character, his habits in science and management, the roots of his success. This diary not only outlines the personality of its author, but has one more important facet: even this diary brings out some hints of the path to be followed by Berg in his fight for Soviet cybernetics.

One psychological detail of this document proves repeatedly that everybody has the same concerns. Although a high-ranking officer, he, like the majority of people, in those wardays lived the hard life.

"It is very cold at home, almost no heating, often there is no electricity and gas, we mostly rely on kerosene stove and kerosene lamps. This is not cosy, poor Marina suffers from cold most of all. This winter is the hardest of all winters since the revolution—no fuel, many plants do not work,

houses are not heated, in general the situation is bad. On the other hand, it's well on the fronts, we have already entered Pomerania and Prussia. The Allies approach the Rhine river and at Cologne they have already crossed it. And the Fascists are still fighting."

The Bergs were not without their small joys:

"... In November we bought two winter overcoats: for Maryasha and Marina. I'm so glad to see their happy faces."

... or moodies:

"I ignore my family. But I cannot live some other way, otherwise the business may decline. Such, it seems, is my lot—no time for personal life. Is it a common thing now? Perhaps. This is a hallmark of the epoch, our speeds, the stormy atmosphere of the time.

"Well, I'd rather go picking lillies-of-the-valley, if only there were no bombs... No nagging any more, I'll have to settle down to prepare a report 'Modern radar equipment' for the Zhukovsky Academy.

"... 23 December. My last encounter with the Chairman of the Council excited me a lot, since issues of extreme importance were on the agenda. All my co-workers are satisfied with the results so far. My work goes on successfully. During the time elapsed I've done much.

"I've been working on the history of the discovery of radio by Popov. Days begin to lengthen. Yesterday we went to the country-side with Marina's friends and walked till 3 o'clock. The weather was fine, the sun was shining and there was a slight frost. I took advantage of the situation and discussed with Marina her academic progress. She has several satisfactory marks, which distresses us very much. Tried to arouse in her an interest in science and knowledge in general. She is an intelligent and good girl."

... It may be that the pithy lines of Berg's diary will help us to produce the likes of Berg.

Chapter Four

The End?

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9 May 1945

Another fighting, back-aching, starving year passed ponderously by. The country met the New Year in anticipation. The Soviet troops were fighting near Budapest, and each day its capture was expected. The Allies, alas, were not helping much, and the Germans were beating them quite a lot. Things were coming to a head, although the hostilities were still to last till May. The V-day was coming, and each citizen was making his or her contribution to its coming sooner.

"... Yesterday, on Sunday, worked on the plan for 1945-46," wrote Berg in his diary on 8 January 1945, "in the evening my wife and I were on a visit for the first time during our stay in Moscow. The place appeared to be overcrowded, it was hot and stuffy. But the people were charming. Left at 12.

"At times my kidneys trouble me—something will prick and the pain will be such that for several minutes it is difficult to breathe, then the pain subsides. What is this—stones? I'll have to put down the dates of the attacks. The last one was on 8 January in my office."

"... 23 January 1945. On Tuesday, 16 January, Maryasha and I went to Leningrad. She was there for the first time since the departure in August 1941, i.e. after more than four years. Leningrad left a painful impression: my city had seriously suffered from war. We stayed with Zina Ivanova. Leningraders live hard—food supplies are meagre. I've seen Galya, she has grown much, she is 16. Lives in a hostel of a communications polytechnic."

In Leningrad he worked hard again. A three-hour report at Smolny for high-ranking officials. The report was welcomed by applause. In the evenings, when the main work was over Berg visited the Academy and the Leningrad Electro-

technical Institute. These establishments were beginning active work despite the fact that basic cadre were not back yet. Some of his old friends had not left the city and had stubbornly fought through the blocade.

Berg was pleased with the attentions of the Leningraders. He was met at the railway terminal, a solemn meeting he had never had in his life.

"I see how they like me and how much they expect from me. Now I feel I'm in a wide avenue and in 1-2 years, it seems, I'll accomplish much. If only I had enough energy and health. I'm full of beans and desire to work, and I see that I'm able to live up to the expectations."

He was congratulated with successes on the front, his colleagues did know that he had made sizable contributions to those victories.

"Our troops on 12 January 1945 started a grandiose offensive over the entire front line and entered East Prussia and Poland, they have only 270 kilometres to march to Berlin. What a panick must be in Germany now. And the Allies are still marking time and have not made even the Balkans. The situation is rather involved, our influence in the Balkans strengthens, which does not please Britain and America. In several days, it seems, all Poland and East Prussia will be cleared of the Germans.

"Our troops are fighting in the centre of Prussia, in Silesia, in Pomerania and Brandenburg. The war is nearing its conclusion. Obviously, the day is not far away when we come to Berlin."

"...Today, 2 February 1945, is a red-letter day," wrote Berg on his return to Moscow, "there was an extended meeting of the Council and 50 men were present, including all the People's Commissars, their deputies and Party organizers. I've made an hour's report, which was completely approved of. Also was approved the general line I have been following. All my workers were pleased very much. The Chairman of the Council was adamant in proving the importance of the business and made a point that commissariats ought not to ignore the radar programme but to provide all the assistance possible."

The import of that meeting would become clear only with the passage of time.

"...When only will this winter end, it is so hard in terms of fuel. Maryasha recovers although her voice is a

bit husky. I'm absolutely well, not a cold in the nose or a cough during the winter."

Berg is "absolutely well", but on the night from 15 to 16 February he fainted and damaged his head. He was ill till 20 February. Acute over-fatigue. When in bed, he read in the history of radio and listened in. Stalin, Roosevelt and Churchill were meeting in the Crimea.

The 23 February whisked Berg from his bed—he was rewarded by Lenin Order for 25-year service in the Red Army. The order was presented by Kalinin. Also were rewarded Kuznetsov, Galler, Levchenko. Kalinin spoke well of the activities of the Council for Radars, about which he had heard much from his son, an associate of Berg. Kalinin held that the present-day youth were highly critical of everything and therefore he was pleased to hear from his son commendations about the Council. He wished him every success in his exceedingly difficult (he stressed this several times) work.

"2 April. Spring is coming, hurrah! It's wet, cold, sun is rare, but still this is spring. On Saturday my family went to see 'Maritsa', and yesterday Marina and I were at the Bolshoi to see 'The Swan Lake'. Splendid."

On 25 April Berg delivered a report at a scientific conference. About what? Well, of course, "Radio-location as a modern epoch of radio". He was received cordially—most of those present were radar people.

And... At last, at long last, at long-long last... the memorial day of 9 May 1945. The Nazies were defeated. Germany capitulated... Everyone was longing for eternal peace, a new epoch seemed to dawn. All the humanity longed for it, but... "But it may well be that this is again just a rest. Radars will have to be improved. Only a dense network of radar defences all over the country can guarantee that we will never be taken aback."

No, defence programmes were not phased out. Just as after the civil war, Soviet experts gave an even more serious thought to defences. It became much easier because soldiers were back from the war, back to shops, fields and universities, and more funds were available for modernization of production. No, the work was not discontinued, but it was done now with a light heart.

People's Commissariat and a Sewing-Machine

"... I haven't written for a long time," we read in Berg's diary an entry of 4 October 1945, "Half a year has passed but how many events. For the first time in this country we create a special modern radar industry. The Council does not allow Commissariats to work "one pulls one way and the other pulls the other". It has brought under its umbrella all the works in this sphere, and life has proved that this path is the most economical and correct one. It's high time to think about creating a separate radar commissariat, but even now we've found our feet. There are many institutes and plants. No words but real achievements. The programme keeps expanding and developing. In a year's time the new industry will appear in a new guise. A more powerful industry than the old radio industry, more advanced by far."

Ukase of the Supreme Soviet of the USSR: among other officials Berg is rewarded with an Order of the Patriotic War, 1st degree.

"This is a first estimation of my work in Moscow, in the Council. I was moved by this appreciation, especially because it was absolutely unexpected."

10 February 1946:

"... Time is flying. Today is Sunday, and I'm sitting in my office, preparing a report covering the entire period of the Council's work, i.e. two and a half years. A reorganization seems to be forthcoming. Now, after the war, there are many changes. I've just finished reading my diaries covering the period since my departure from Samarkand in 1943. How much has been experienced since! How many ordeals! How much work! But the result is not half bad, however. The Council has gained footing and has become an authoritative activity.

"The institutes report to it. Plants are working at full speed. A powerful industrial basis has been created. Personnel have been trained. But the management of the whole radar thing should be reorganized. The Council of People's Commissars asked me to prepare materials for making a decision concerning the establishment of a separate radar commissariat. This is what I've long considered necessary.

"I'm in high spirits. At home, too, there are some improvements. Maryasha has a new sewing-machine, and I a new fur leather jacket.

"What is ahead?"

Ahead were good news. In 1946 Berg became an Academician.

From 1947 to 1952 he was carrying out responsible scientific and managerial work. Berg was elected a member of the Bureau of Technical Sciences of the Academy of Sciences of the USSR, and he immediately started lobbying for more places in the Academy for radio people. Ever since many major workers in radio sciences became Academicians and Corresponding Members. He entered the boards of the journals *Electricity, Radio Engineering, Automatics and Telemechanics*. Characteristically, he could not just "belong". He agreed only to active involvement.

Demobilized military radio operators restored SW radio amateur movement. They needed a leader, and so they elected Berg a Deputy Chairman of the Committee of Radio Amateurs.

Fraiman used to say that springs of scientific and technical amateur activity striking in distant corners of the country should be helped in merging to form a stream of science. Only books could make this. Berg became a founder of a series "Mass Radio Library", he worked on its board, and invited major radio experts. He shaped the spirit, style and contents of that flow of books.

Mental Callisthenics

Nearly a six-year break in records. During this period radar became real science, engineering and industry, and that complex was already playing important role in the general balance of national industries. Radar worked for defence. And some of its progenitors were beginning to think of retirement: they've worked hard, and now let the young bear the torch.

"We're getting old," wrote Berg on 7 November 1951 at his summer cottage at Lutsino," Soon I'll be 59, Maryasha is over 50. In 1952 Marina graduates at the University. Perhaps it's high time to quit that mad manager's work, and at least in my declining years to concentrate on active research."

The more so that all his former scientific contributions were appreciated.

In 1951 the Academy of Sciences of the USSR awarded

him with a A. S. Popov Gold Medal for "all outstanding contributions to radio engineering". Insiders knew that in addition to all his articles, books and textbooks, prominent among his contributions were his works on radar, although at the time they were not entered into the volumes of Berg's *Collected Works.*

The appreciation aroused additional interest in active scientific research. But...

In that same year the Presidium of the Academy of Sciences of the USSR appointed Berg Chairman of the All-Union Scientific Council for Radiophysics and Radio Engineering (Radiocouncil). Under its umbrella gathered the foremost radio specialists of the country. This was a honourable post, a new possibility to influence the research on radio and an additional substantial load.

But his own research occupied only his odd moments, weekends and holidays. He concentrated on theory and hoped that it would come in handy some time in future. Maybe he would be transferred to the Naval Academy. Also, he needed more time for rest, he got tired quickly, and was often unwell.

"... My work is useful, no doubt. We are making important things. But at the same time there remains a feeling of dissatisfaction, since I'm doing too little science."

He was a man of science, every inch of him, and no amount of management, even the most important management, could separate him from active science.

"I've been thinking much about my future. What about my scientific plans, which I nurture from my youth? Or, maybe it is already too late to make any plans? The life is coming to an end. But I'm not short of energy and endeavour. I've always considered that it's never late to start from the beginning. So I thought in 1918, when I decided to retrain myself and entered the university."

Berg speculated:

"The kins of my mother and my grandfather were all long-lived: mother died at 82, grandfather at 89. By my constitution I'm following their steps. Hence I'll live another 20 years. During this time space I can accomplish much. True, these are going to be years of gradually declining capacity for work. Twenty years ago I was 38, it was in 1931—I just returned from America. It seems to have been quite recently. But during these 20 years I've made quite

a lot. Hence 20 years are quite a long period and I should start working as in old days. At that time I took strict account of the hours of my work. Then too I had to snatch them. And the system helped me to save time. And what about trying once more. Maybe I'll live not so long, even much less, say a year or two, but the hours of work will be a source of satisfaction."

He was looking forward to writing a good book on the uses of calculus and Fourier series in radio. He admitted that in recent years he had lagged behind the frontiers. An Academician more than anybody else must study constantly, since the science keeps moving ahead.

"In old age I must again return to theory. In the remaining years I'll hardly make a serious contribution. But each hour of independent theoretical studies will help me in my practical activities. Callisthenics for the brain, training of intellect, maintaining or even improving the qualification will be the immediate results of my theoretical work, let alone satisfaction."

And so in several years that busy man mastered the latest results in mathematics, especially operator calculus, of importance in pulsed circuit design. He had planned to squeeze these studies into 800-1000 hours, but it was next to impossible to find a couple of hours in a tightly packed working day.

"I have to work regularly and take more severe account of the work done," wrote he with dissatisfaction," What arrangement is to be established? I think as follows:

"Mathematics—reading up and covering new areas that have proved their usefulness in physics and engineering.

"New results in electrodynamics and theoretical electronics, including field theory.

"Special-purpose radio engineering, i.e. high-frequency devices and related electromechanics. Particular attention should be paid to nonstationary processes. Harmonic analysis in general and as applied to radio engineering (I covered much ground during the last year and during my illness in the spring of 1951). An Academician again studies, studies, studies, like a student.

The Die is Cast

Berg was again facing a turning point. A. Nesmeyanov, President of the Academy of Sciences, invited him to come to work to the Academy of Sciences. Berg agreed. But what about his current post? The Minister of Defence agreed to Berg's coming over to the Academy of Sciences on the understanding that he remained with his previous field as a consultant.

Berg "boosted" science, putting his back into studies.

"Thus, after I've taken my decision on 7 November 1951, I've worked about 350 hours—not bad. Got my hand in again, nearly as 10-15 years before. I've already mapped out a plan of the book I'd like to write. The book will be entitled *Harmonic Analysis in Radio Engineering*. In a fundamental, consistent and clear way, it will supply research workers and radio engineers with the necessary topics in harmonic analysis. Plenty of examples.

"If I come to work to the Academy of Sciences, I'll have more time to spare and I'll be able to devote to science 100 hours or more a month, and so I shall be able to write the book within reasonable time.

"I'm happy that I manage to realize my decision of 7 November. Again I believe that I'm able to make serious contributions to science.

"8 April 1952. Continue to take harmonic analysis. On 5 April, I applied for dismissal from administrative work. The die is cast. I staked all. The objective is to be able to concentrate on science.

"I study the history and philosophy of Marxism. Learned much new and interesting, nay absolutely necessary for me. I havn't even heard of some philosophical polemics. These disputes are abviously carrying on into modern times.

Berg made another attempt to focus on science, by coming over to the Academy of Science. And this attempt yielded peculiar results. He ended up with even more work on his hands. Each makes life easier his own way. Berg's vehement character did not enable him simply to enjoy the academic silence of a laboratory. He had to shoulder some other responsibilities.

Berg suggested to organize within the Academy of Sciences an Institute of Radio Engineering and Electronics. He

was backed up by the Presidium. The Government decided to establish the Institute.

A decision of the Presidium of the Academy of Sciences read as follows: "Organization of the Institute of Radio Engineering and Electronics of the Academy of Sciences of the USSR (IRE) is assigned to Chairman of Radiocouncil Academician A. I. Berg."

Before long the Institute was organized and Berg was appointed its director. He recruited a team of enthusiasts, found premises and set out to reconstruct it. He pictured the new institute as a brain centre for up-to-the-minute radioelectronics. The very word "radioelectronics" had been coined by Berg in the process of discussions about the statute of the Institute to stress the indelible connection of radio engineering with electronics at the present stage of development of science.

The nucleus of the Institute was Academicians B. Vvedensky, and V. Kotelnikov, Corresponding Members N. Devyatkov, D. Zernov, Yu. Kobzarev, A. Pistolkors and V. Siforov. All of them were united by many years of service to science and mutual respect.

Together with Vvedensky the Institute acquired a highly qualified team of specialists in radiowave propagation. Kotelnikov, Kobzarev and Siforov initiated programmes in communications, noise immunity, coding, and information theory, a discipline that at the time was having its heyday. Devyatkov and Zernov headed efforts in the fields of microwave electronics, cathode electronics, and photoelectronics. Pistolkors, in addition to aerial and waveguide studies, provided guidance to investigations into then new materials—ferrites—which featured interesting magnetic properties with semiconductor-type characteristics.

From the Physics Institute of the Academy of Sciences came a small group of workers dealing with quantum electronics and frequency standards. Berg was planning to have a semiconductor department.

Scientific workers occupied and equipped premises immediately after they had been left by repairmen. Staffing with established teams enabled the Institute to do without a period of infancy and children's diseases. It immediately entered a period of productive adolescence.

Berg, Kotelnikov and other leading workers of the Insti-

tute were planning systematic expansion of the programmes, premises, and staff.

Berg was looking forward to confining his activities to the Institute.

But fate decided otherwise.

Diagnosis "Hopeless"

International situation since the end of the war was becoming ever more complex. The danger of atomic death hung over the world. The atmosphere was getting hotter. Future seemed sombre, against the background of an atomic war and the outlooks of absurd destruction and catastrophe the world seemed unstable. The Party was taking measures to strengthen the country's defences. Political, technical and cultural levels of Soviet citizens were going up noticeably. Young recruits in the Forces were remarkable young men. They were mastering the modern armaments and materiel. But teaching the young soldiers and developing ever more powerful armaments required experienced personnel. And the times were not ripe yet for veterans to retire.

On 8 June 1953 Berg was unexpectedly summoned by Minister of Defence Marshal N. Bulganin and asked to report on the state-of-the-art in radars. Then he required that Berg submitted in writing his suggestions on reorganizations and improvements.

The final result of this overwhelmed Berg: on 18 September 1953 he was appointed Deputy Minister of Defence of the USSR.

"Never thought to get into such a hell at an age of 60. I was dreaming of taking a quieter job, but that's what has come out of this. Ahead lie so many troubles, such a huge and responsible work that my head is spinning. But I'm sure that I'll cope. My experience is enormous and I do know that help will come."

More than a decade had passed since he was put at the head of the national radar programme. During the last four years he had been concentrating on other things. IRE became one of the best establishments in the country. And now again he became a leading military commander. He only managed to relinquish the directorship of IRE, but for many years he would be on the Board of the Institute. At first it was hard. As in older days, at the Commissariat

of Electrical Industry, some officers at the Ministry were against his appointment. But the majority were with him. The time was different, and so were people.

"I'm occupied with responsible managerial work, which is so far little noticeable," wrote Berg in his diary. "The head is full of ideas concerning improvements in our radar systems. Unfortunately, I'm 60. Shall I have enough time and health to affect the progress of works?"

Now Berg only rarely turned to his diary—too much work, strenuous situation in the world. Berg was well, worked much, but got tired terribly, old age, obviously told on him.

"Lutsino, Saturday, 2 October 1955.

"Today I was given an assistant, Rear-Admiral Varaksin. I've long being asking for that. He is going to be of much help.

"One of these days I'm going to have my 3-week vocations for the last year. In autumn Maryasha, Marina and I stayed at the Fabritsius Sanatorium at Sochi. We were having a good time there. I was playing tennis, we were walking, bathing.

"We now have a splendid sheep-dog Mishka, an intelligent, tender creature, we all love him so much. Our orchard matured and became very beautiful. Spring is coming. Very much snow, more than in the previous years.

"... No, I've lived my life not in vain. Although I've discovered no law, made no inventions, but for 30 years now I've worked in radioelectronics and undoubtedly was of some use for my country. I don't know how long I shall live and work, but I'm eager to make much more. My interest in work hasn't waned, no signs of languor, senility, only I get tired sooner than before. But, after all, I work much.

"I've been keeping this concise diary for 14 years now. It contains a record of the entire history of struggles for new technology. Is anybody going to read it?"

This is the last record. It might become the last one in his life, should the later happening have another end.

And happened the following. In June Berg went to Leningrad. The Deputy Minister's working day lasted 15-20 hours. But in Leningrad Berg found time to deliver several lectures for the students at the Electrotechnical Institute and some military academies. On his way from Kronshtadt

he visited the Pulkovo Observatory, to inquire after the state-of-the-art of radioastronomy. Radioastronomers were complaining about the heightened level of interference. He wanted to check first-hand the effectiveness of new measures taken to shield the space hydrogen line (21 centimetres) and other ranges of immense importance as information-bearers about the structure and evolution of the Universe. Despite all, he agreed to appear before a workers' audience. And when Berg was returning back to Moscow by train at 3 a.m. on 20 June an accute pain pierced his breast and he fainted. Maryanna and two aides accompanying him got up alarmed by a sound signal; at the last moment Berg managed to press the button. It was night, an old man was dying and there was no doctor within easy reach. Both aides had no idea of what was to be done.

The passengers on the train were awakened by an announcement over the public address system that a man was dying and a doctor, if any, was asked to come to the last carriage urgently. The announcement was made repeatedly a dozen times till a man out of breath rushed into the carriage of the Deputy Minister. Having proclaimed himself a doctor, he ordered to place ice on the heart. From the restaurant a bag of ice was brought and used. The result was quite unexpected. The patient got cool, his pulse became weak. The train was stopped at Klin, from the nearest polyclinic an old doctor came, her name in the heat of the moment was forgotten, unfortunately. She opened the window of the compartment, let fresh air in and threw out the ice. Gave oxygen to the patient and stimulated his heart. In short, she made everything in her powers. She explained to Marianna that her husband had a cardiospasm. They should have given him some nitroglycerin and the spasm would have been removed. It was quite possible that under the spasm in the heart a small clot of blood had formed and something hot had to be applied to the heart for the clot to resolve.

The old woman stayed with the patient through the rest of the trip. And it only thanks to her that Berg was brought alive to Moscow. Had the ice stayed on, Berg's heart would have stopped beating near Klin.

In Moscow he was rushed to a hospital, but there Marianna was told—hopeless.

Third

Life

With the passage of time,
Art becomes more scientific,
and Science more artistic; having parted in the foothills they will meet some time on the summit.

from **G. Flaubert**

Chapter One

In Jest and In Earnest

Tsunami

Really, wonders do happen in all times, even in medicine. A year and a half Berg fought for life. Death retreated. After a three-side infarction, which stroke him on 20 June 1956 in the train, many long months passed. June, July, August—the Kremlin Hospital; September, October, November—the Barvikha Sanatorium. Then Lutsino, his summer residence at Zvenigorod. He was still unfit. In mid-1957 Berg applies for retirement from his post of Deputy Minister and his retirement was granted.

Again a hospital, again a sanatorium. When I met him in May 1958, he was an ill sad old man. Lone—a tragedy at home, and he was alone in a large empty flat. Without any plans—what plans may be made when life hangs by a thread. Without any hope—what hopes may be cherished, when you are no more fit for work. The illness whispered that at 65 it would be unreal to make serious plans for the future.

If at that time somebody told him that in a year he would be in the heat of fight for Soviet cybernetics, and that in three years, on 14 June 1961, at 68 he would say "hello" to his new daughter Rita, and at 70 he would be a Hero of Socialist Labour, he would hardly have believed it.

Hardly have believed? But why then a stack of books kept growing at the bed-side. Why did a nurse have to use tricks and exhortations to take away books and journals from that refractory patient, to hide his spectacles and ball-pen? Topics of his talks with physicians strayed away from infarction: they argued about some living automata, compared the nervous system to a telephone station. A glance at the then records of Berg's immediately brings to mind his diary of war and post-war days—the same intensity of spiritual life, the same passion, the same consistency of aim, only now Berg's thoughts were concentrated on another thing. Not radars, the be-all and end-all of the previous pages, but something different, a thing with a strange and then esoteric name.

... Radio, which in the 1920-30s came on the scene as an unrivalled communication means, and in the early 1940s as a brilliant combat arm, by the late 1940s blossomed violently. It yielded a staggering spin-off in the form of the computer, a product of the human brain, so audacious that it was promoted to the rank of "artificial brain". And around the new off-spring of electronics waged such a war that willy-nilly the computer became a tool of ideology.

To get carried away is human. This asset is inherent in us, just like the powers to think and work. And no wonder then that the coming of the computer set the fantasy racing not only in the men in the street, but also in men of letters and science. Newspapers, magazines and books throughout the world abounded in prognostications of things good and bad in the "electronic brain", of hazards concealed in its devilish might.

I'll here draw on my personal feelings at the time, when I first encountered the new science. My attitudes were hardly different from those of the average man and from the response of an engineer, because at the time I was a student of radio and was in a fairly good position to understand the ideas behind the computer.

This happened early in the 1950s at a meeting of the Popov Society of Radio Engineering and Electrical Com-

munications. Among the many reports was one with a short title "Cybernetics". The author was the prominent Czech Academician E. Kolman, a mathematician and philosopher.

The report was like a bombshell. Some fantastic predictions, nearly mistic revelations. Also striking was the format of the report. As if before your very eyes the scholar took an apple, peeled it and... under the peel there was a chick. He was speaking about common-place things, such as electronics, automatics, mathematics, laws governing the workings of machinery. But, quite unexpectedly, you found yourself seeing and feeling the ways in which the human organism was functioning, and the brain was thinking. At that time those were nearly sacrilegious correlations, but the beautiful and tempting analogies and predictions captivated you at once. No wonder that cybernetics not entered but stormed into our time.

The beauty of it was that the speaker was discussing not some weird and wonderful discoveries, yet unknown to humanity, but some trivial phenomena. The computer was constructed from building blocks familiar to any radioman—valves, inductors, capacitors, and resistors. At the turn of the century they surprised scientists by their ability to produce radiowaves and serve as means of communication. They also made radar capable of seeing a hostile plane or ship many kilometres away and thus helped to destroy it. And now, these same trivial components were demonstrating another facet of their, possibly inexhaustible, nature. An array of electronic circuits, more involved than radar, could be a counterpart of a human brain. A counterpart in the sense that these elementary radio components could now perform cumbersome mathematical computations; shoulder some of the problems equal only to the human brain: to draw conclusions, to translate from foreign languages, to analyze tangled situations, to make predictions.

Commonplace details organized into enormous arrays, called computers, were able not only to carry out computations but also to control nearly anything: planes, trains, blast furnaces, shops, plants.

The earliest days of those wondrous machines bewitched, bothered and bewildered. Many writers, journalists and even scholars did not spare black colours describing the tragic future of human beings, and warned against the society of

thinking automata. Man, they maintained, would be ousted by machines. An era of steel people was coming.

The prospect scared stiff even the father of cybernetics Norbert Wiener. He remembered the medieval legend that a Prague rabbi, Lev ben Becalell, who flourished at the time of Rudolf II, created Golem, a clay slave, wood-cutter and a water-bearer. By putting into his mouth a note with a cabalistic god's name, the rabbi revived the clay monster. But once the rabbi went away and forgot to take away the note, and so Golem wrecked everything, and flooded the house. The flood threatened the neighbourhood till the rabbi himself came and destroyed Golem.

And what if cybernetic machines would rebel too? The last chapters of Wiener's novel *God and Golem, Inc.* suggest that the author wouldn't mind destroying a Golem of his own making. But producing him he hadn't on his mind any sensation. Everything was exceedingly simple, and his studies contained no hint of an impending scientific tsunami.

Why God!

In the summer of 1946 Wiener was invited to France at a mathematical conference. En route he stayed in England to see his colleagues at the National Physical Laboratory at Teddington, at London, Cambridge and Manchester Universities. And at Manchester he first learnt that scientists there were planning to start an effort on high-speed computers. And at Teddington, Turing, an obscure worker then expounded ideas to fuse mathematical logics and electronics. Much to his surprise Wiener found out that the ideas pursued here were exactly those that formed the subject of his speculations and the conclusions of his own works. He hit upon an idea to write a book highlighting the generality of laws in automatic control, production management, and the nervous system. He even went so far as to make arrangements with a Paris publishing-house.

Back at America, Wiener set out to write the book. But from the very beginning he encountered a snag—how was one to call the subject he was going to write about? The topic was automated factories with a sophisticated control system. Over that "nervous" network, a shade less sophisticated than the nervous system responsible for the com-

munications within the organism and for its relations to the environment, would circulate flows of information about the functioning of individual parts of the huge apparatus.

To work out the name of the new science, Wiener by tradition started groping for some Greek word meening "bearing information". His first idea was "angelos". But then it resembled "angel" or "a messenger of gods". Gods had nothing to do with it. What other candidate? And now Wiener chanced upon the word "kybernetes", which came, he thought, from the Dutch and meant "navigator".

But even in the Dutch language the word was a guest. Long before Christ the ancient Greeks were expert seafarers. The Greek for the mariner was "nautes", the captain "hypernautes", from "hyper"—over, above; seamanship was "hypernautika". So, as a result of language mutations the word "cybernetics" was born. The kindred French is "gouvernail", the helm. Later on, rulers were called governers, and the ruling board, government. Hardly many suspected that these were corrupted Greek words. Interestingly, the word "cybernetics", which was received as an absolutely new coinage, had been known to men of science. It was used, say, by Plato. It was known to the French physicist Ampere, who was fond of classification of sciences. It was widely employed by the British physicist Maxwell in his famous publication on automatic control. But neither Wiener nor his friends making research on automatic control in various fields were aware of the fact that their newly-coined "cybernetics" had already been used in science.

Anyway, in 1948 a Paris publishing house issued a book with a strange name *Cybernetics.*

Neither Wiener nor his publishers put much stock in that book. And they were amazed to find it a best-seller. Wiener was showered with invitations for lectures, more booklets and books about cybernetics, he was invited to various countries. True, the enthusiasm was quenched unexpectedly. A signal came from Spain. It was understood there that the concept of cybernetics involves social relations. Wiener was forbidden to read his lectures in Spanish, only in French, so that as few as possible could understand him. This was because he did not confine cybernetics to engineering alone.

Quite oddly, Wiener compared human society to a bridge. If a bridge is fixed rigidly, its structures will suffer internal stresses. Such a bridge will not last long. Only by

leaving one end of the bridge slidingly fit, the builder can make the bridge "breathe". Likewise, rigid organization of a society, a tyranny, is fatal for it. No foreign structures should be forced upon people.

In his autobiographic book Wiener confessed that nobody, even he himself, could imagine the agitation that his ideas might arouse. His intentions were quite modest: to acquaint the public with the new information theory and the new prediction theory, whose foundations had been laid by early Kolmogorov's works and Wiener's own studies of the probable motion of an aircraft for anti-aircraft gunfire; and to draw analogies between the human nervous system and the computer.

Wiener's contribution to science turned out to be by far more serious. With his formidable erudition and scope he could hardly confine himself to one specific problem. He held that it was clear to him nearly from the very beginning that the new concepts of communications and control entail a new understanding of man and human knowledge about the Universe and society.

Beginnings

The ideas of cybernetics were spreading like wild fire. The control of an automated factory and even more so of a human society were as yet issues of a distant future, but theory was already busy, erecting a foundation for practice. At first scientists sought to solve specific questions of information transmission (information is a sort of a cement for a society or an organism), questions of communications, questions of predetermined responses or environment-conditioned responses.

Cybernetics, like any scientific discipline, took some time in shaping. It, like a child, had a complicated infancy. Whereas in other countries its advances were written up before they were worth it, when it was still in its nappies, in the Soviet Union some scientists believed that there was no such science at all, even when it had been out of its infancy. What was worse, some even were out to blacken the new science.

It took Berg to discern the immense potentialities of that problem child. Academician Alexander Mints, a friend and supporter of Berg, said: "The recognized and glorious ra-

diotechnician Academician Berg changed the circle of his interests. And this is not so simple when you are in your sixties. In this country he became the leader of the young science, cybernetics. The heroism of this move lies not only in that he had to turn over a new leaf at that age, but also in that he flung himself into a field, which at first was cursed by some philosophers as a false science, as a manifestation of bourgeois idealism. That is why admirers of Berg call that science "cy-BERG-netics".

Yes, Academician and Admiral Berg is fighting again. This time he maneuvres among scientific "mine fields". What other word would serve better here to describe the obstacles through which the Soviet ship *Cybernetics* was struggling in the 1950s.

On Berg's desk there lay for a long time a thick folder. Some time it will be given a due place in a Museum of Science, but not near a loom, stone axe or a wooden plough, but near daggers and poisoned arrows. The folder was entitled "Anticybernetics", and contained publications of ignorant and short-sighted authors.

Happily, the anticybernetic period was short. As early as 1964 the American journal *Air Force* wrote: "The stress of the Soviet Union on cybernetics is the greatest threat to the West", and "cybernetics has attracted the attention of the best brains in the USSR".

Berg was one of those who saw in the novel approach a regular progress of thought. Moreover, cybernetics was the focus of all the scientific interests of Berg, and a possibility to apply his knowledge to solve wider problems.

When asked why he fell in love with cybernetics, Berg advised to look up the Great Soviet Encyclopaedia, the entry "Navigator's Service". Among the tasks of a navigator the Encyclopaedia lists the training of personnel, preparation of devices, exploration of the region of action, computations required for making decisions and planning the navigation, complex application of all the methods available to achieve accurate navigation.

Exactly the same tasks has cybernetics. Only in a much wider context, and not only for seafarers, but also for commanders of national economies.

So it was impossible for Berg not to become fond of cybernetics, a daughter of electronics and a sister of navigation. Even the very word "cybernetics" is synonymous with

"navigator". It is worth stressing that for Berg cybernetics was an inevitable, logical pursuit, one that stemmed from all his tastes and inclinations.

Knowing the ardent temperament of Berg and his straightforward character, one can imagine with what zeal he plunged into the fight for cybernetics. Dozens of articles and reports to clarify its meaning, vehement, polemic-laiden, militant; struggles for industrial applications of computers, the armamentarium of new technology; establishment of institutes—all the armaments were deployed by Berg in order to protect and introduce cybernetics. A fighter and scientist, he could face the music and could take a direct path to an aim.

"Although the Russians sing the praises of Norbert Wiener, they have their own founder of cybernetics, a 70-year-old Aksel Ivanovich Berg, an Academician and Admiral, who is to be credited to a large degree with the development of Soviet radar during the Second World War,"—this curious characteristic was given to Berg by the above-mentioned *Air Force* (1964).

Together with cybernetics Berg's circle of interests got enriched by medicine and biology, teaching and psychology, geology and economics. Berg became head of the Council for Cybernetics of the Academy of Sciences of the USSR.

It is worth noting here that in the shortest time possible Soviet scientists caught up with the rest of the world and reached frontiers of cybernetics. Admittedly, at the time the Council was established cybernetics was still in its infancy (the Council was instituted exactly for the purpose of fighting for it, to disperse the fog of suspicion, to organize research institutes and to train experts).

But to say that at the time there was no Soviet cybernetics would be a mistake. Despite the interdiction barrage Soviet cybernetics was stubbornly fighting its way through. It is impossible to stop scientific thought. A real investigator, if he has got a brain-wave or learned about some novel idea of a colleague, national or foreign, will inevitably want to test, check it by experiment, calculation or seek opinions of his mates. Science knows no obstacles. During the time, when magazines were publishing articles collected by Berg in his "Anticybernetics" folder, in dozens of Soviet institutes cybernetics was making its appearance in labours to be embodied in real devices and machines.

It could not but come to the fore, once a scientific worker turned to the issues of automatic control in any object, machine or living organism. To cut a long story short, cybernetics lingered on despite suspicion and ignoring.

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Wellsprings

Again I would like to draw on my personal recollections. Once I came as a journalist to one institute. I entered a laboratory, a sombre room. It seemed that there was nobody there. I made a couple of steps and cried out in surprise. Something gray was crawling to me from under a table. Having heard my cry the something stopped. In a short while it hissed again, moved on and began to turn describing a circle on the floor. Having finished the circle and hissing in the same monotonic way, it crawled on and then again went in a circle. I stepped back and opened the door to a lit corridor, and here the outlandish animal—I had no doubt that that was a living creature—stopped moving in a circle and moved directly in my direction.

"Stay, will you," a voice said in the room.

I stopped, so did my pursuer.

"I think it is with her that you wanted to get acquainted." With those words, barely keeping a straight face, a tall young man, whom I had not noticed before stepped forth from a corner of the room.

"I was informed by telephone that you are coming and so I was training my turtle," he said, now grinning openly.

So I got acquainted with an astounding cybernetic animal, and one of its creators, Alexander Petrovsky.

The "turtle" really resembled a living one, although it was just a primitive box, sardined with relays, lamps, photovoltaic cells, microphones, and accumulator batteries. It was scuttling in the Institute of Automatics and Telemechanics of the Academy of Sciences of the USSR. It ran about, circumvented obstacles, stopped when somebody clapped hands as if in fright, looked for a lamp hidden behind a sofa. It imitated some conditioned reflexes, inherent in animals and even learned a couple of simple commands.

Training? A bit of overstatement, but close to truth. When the "turtle" was going around his foot butting into it and as if thinking of "where to go now", Petrovsky clapped his hands. And the "turtle" remembered this. Of course,

not immediately, but remembered. It developed a "conditioned reflex" for a clap. It understood that a clap came when it was going round an obstacle and now instead of standing still, "playing dead", as it did before, the "turtle" received the clap as a signal to start going round an invisible obstacle. It behaved in a manner like a Pavlovian dog. If a dog during each feeding heard the toll of a gong, it started exuding saliva not only at the sight of food but also at the stroke of the gong. Similar reflexes Petrovsky had modelled in his "turtle". The year was 1957. But several years before similar turtles were constructed by Gray Walter. His turtles imitated the feeling of hunger. When batteries that powered them were running low, the turtles would make for a predetermined place of "feeding", where they took in electricity till their batteries were charged. At about the same time the father of cybernetics N. Wiener amused himself by designing "moths" attracted by light.

And soon the scientific world heard about the famous iron mouse of Shannon that in search of a piece of "fat"—a magnet—at first made a thorough search of an involved maze, and after several trials it rushed to the "fat" immediately along the shortest path. It would remember it as a result of several attempts. Then came a funny family of electronic "foxes"—brother Job and sister Barbara, who played, cut capers, fooled around, and stroked each other. And before long electronic "poetess" Calliope made her appearance; she could make poems, draw, invent designs for Byzantine carpets.

These all contrivances were direct descendants of the Leningrad mechanical dog manufactured back in 1929 by G. Babat, and the French robot-dog exhibited at the Paris Radio exhibition. The French dog amused public a lot: it ran after a person who held a lantern but barked and turned away if the lantern was brought near its nose. That electronic dog had to go to the New York exhibition, but it "died" tragically in 1939. It was crashed by a car whose headlights attracted it.

"Foxes", "mice" and "turtles" are toys, funny and charming. And not that complex. In the wake of scientists came students and even schoolchildren. They were not emulating known circuits but rather inventing something new. So two "turtles" were taught to play soccer, and they were chasing a ball ridiculously copying tricks of animals.

Yes, those were toys, but even then scientists treated them as precursors of future "intelligent" machines.

"Well", said Petrovsky meditatively, "send my 'turtle', its more sophisticated version of course, to Mars or the Moon. It won't get lost, it'll take bearings splendidly. And if the task of the small "turtle" is only to search for light, the task of a larger "turtle" can be made more complex. Undoubtedly, it will carry out everything we shall teach her on Earth: explore the landscape, collect samples of minerals and soils."

Even then many were thinking about more complicated problems. If there exists the "turtle", why shouldn't one attempt to produce an automated transport or agricultural machine with "intelligent" behaviour, or develop automatic regulator of production processes, flexible enough to respond to changes in the quality of raw materials, wear of tools, etc., so that to facilitate the work of man?

"Using mechanisms similar to the 'turtle'," Petrovsky went on, "an automatic air traffic controller for an airport can be manufactured. Such a machine will receive information from aircraft coming in for landing and will give priority to those which have an ill person on board or ran low of fuel. In an emergency the machine will be able to direct a plane on a stand-by runway".

"On the same principle a dispatcher on railway stations can work", Alexander Petrovsky was musing and I was scribling in my note-book, "When forming up freight trains the device will be able to take into account not only the time of arrival of carriages, but also the nature of goods. Perishables and urgents will be given priority. This will not only improve the availability of rolling stock, but also will simplify the work of couplers and the dispatcher.

"At a post-office, too, such an automaton will be indispensable. While sorting out post it can take into account not only the schedule of departures of all the trains and airplanes but also the amount of correspondence and its urgency. The memory of the automatic sorter will contain the entire geographic map of the country and it will be able to map out the simplest and fastest route."

Dreaming about the automatic dispatcher Petrovsky had not known yet that the problem was challenging beyond belief. It took nearly a decade for scientists to understand that the answer would not only call for more powerful and

speedy computers, but also for a new section of cybernetics, heuristic programming, whose aim was to teach the computer to simulate the thinking of man and to endow it with a measure of intuition.

Such machines were not available at the time, and nobody gave any thought to heuristic programming, but at the institute, where the "turtle" was running about, a computer was being developed that was able to handle a problem similar to that posed by Shannon before his "mouse". Physically, that was a fairly simple combination of relays, which in case of need remained on for a while so as to "remember" the solution to a problem. The machine I had seen was in essence a model. When its designer, Ivanov, pressed some button, in a short time, during which something mysterious occurred within the computer, the glowing trace of a lightning crossed the screen. Ivanov grinned happily. When, several minutes later, he again switched on the device and the lightning followed the same track, the grin became wider.

"Remembered", he was jubilant, "remembered the task."

Then he would take another run, changing the task, and the lightning—that was the trace of a "mouse" nosing its way from an initial point to the place in the maze where there was a piece of "fat"—changed its track. The device, of course, contained no mouse, it was just a labirinth of electric wiring. And when Ivanov pressed the button, this initiated hundreds of switchings in the circuit with the result that the only network was made for electric current. The circuit had the property that for a while this arrangement of switches and relays was remembered. If Ivanov again switched on the device by pressing the same button, the current went the same way. If the button had not been used for a long time, the relays demagnetized, forgot the way they had been connected the last time. That model initiated new types of modern automatic telephone exchanges.

But then Ivanov, like Petrovsky, was dreaming:

"Just imagine how an automaton based on this principle will work, say for bibliographic purposes, a bibliograph-automaton. The 'fat' in such a machine is one of the cells containing bibliographic cards arranged by scientific disciplines, arts, etc., large sections being subdivided into smaller ones. The latter will in turn be broken down into yet smaller ones, thus forming some sort of search maze.

Having received an inquiry for some publication the machine will, like the 'mouse', try all the cells of its 'memory' till it bumps into the 'fat'. Then the automaton will give out required information. With repeated enquiries it will make this much faster. The same is true of new telephone exchanges. Busy numbers will be given faster. The exchange will remember the shortest way to them. But if there is a long break in calling, the paths will be forgotten and the exchange will have to be taught anew."

These machines and many others could have made their appearance much earlier. They took longer in coming because of the derangement introduced by some ignoramuses. They have a way of voicing their opinions first—they need no time for thinking. And in this country, unfortunately, only a few had any idea of the true meaning of cybernetics. Some have not even heard of it, others waved it away, yet others even cracked down on it. And our scientists had to fight their way through not only natural obstacles posed by nature itself, but also obstacles of our own making, quite unnecessary ones. All the more credit should go to them because they managed to get over those problems and today we are abreast with other countries, and at times even ahead of them.

"In the middle of 1950s several electronic computing machines made their appearance in the USSR. They wouldn't have taken the cake for reliability and speed of course, but were of help already in some involved mathematical computations and were applied in some control systems at industrial projects. Perhaps many remember long queues for newspapers and magazines covering those happenings, the huge auditoria of the conferences, which were then called diffidently conferences on electronic computating facilities—they were prudently not referred to as cybernetical. Many remember how eagerly were received the reports by Lyapunov, Panov, Shura-Bura, Gutenmakher and other early Soviet cyberneticists with new evidence about "intelligent" machines, about new constructions of "memory", more capacious, fast.

But that was not victory as yet, rather single skirmishes. New results may well be obtained by individual workers, one or several laboratories. But for a science to become a foundation of industry and state power requires some personality able to piece together individual successes, combine

all efforts into one stream, into one striking force. A river capable of unrooting huge oaks and striking its way through mountains is composed of individual wellsprings, of many droplets.

Advance

The dispersed contributions of individual scientists and small teams were beginning to bear fruit. And time came when it became clear to all those concerned that without adequate guidance and adequate coordination no further progress was possible. It was then that Presidium of the Academy of Sciences decided to establish a Scientific Council for Cybernetics whose task would be to coordinate all the efforts in appropriate fields. Chairman of the Council was Berg.

What was to be done first? The same thing, as in the naval radiodays, to work out a programme of action, to organize institutes and plants, to train personnel. What else? The same thing, as in Berg's radar campaign, namely intensive, clever, exciting propaganda of the value and potentialities of the new science; raising funds for it; struggles against shelving the world's achievements—the dangerous ostrich policy.

This required a close and unbiased look at the state-of-the-art in cybernetics in the world in order to sift the wheat from the chaff. And then it was necessary to make those who doubted the usefulness of this branch of knowledge to change their mind and to join forces for the benefit of national science. But the main thing was to understand what was behind the fallacies, and misunderstanding.

It would seem that to put into shape the work of the Council was for Berg a problem of small proportions, everybody remembered his activities in the Council for Radar and the resultant prosperity of radar industry. But it was not exactly the case of history repeating itself. In certain respects both the problem itself and the general atmosphere around it turned out to be more complex. The new science stormed into many disciplines that appeared to be unprepared to accept its concepts and techniques. But breaking a routine is always difficult.

Only at first the Council could manage with several members—a Chairman and three aides—all part-time work-

ers. Later it started splitting into sections, just as cybernetics itself started to divide into subdisciplines. The Council turned into a union of many councils.

In complexity cybernetics was a far cry from radar. It appeared to be a focus of problems, a bouquet of sciences although, united by a common idea. This was the science of control in the widest sense of the word: in engineering, in medicine, in teaching—to cut a long story short, in animate and inanimate nature.

It was not for nothing that cybernetics was termed a synthetic science. It uncovers common laws in disparate spheres of nature and human society. It turned out to be literally all-embracing, and so under the umbrella of the Council came representatives of various sciences, and Berg as a leader, helmsman and coordinator found himself studying again, reading up on sciences having nothing to do with his traditional fields.

In a year after the establishment of the Council, in the journal *Questions of Philosophy*, 5, 1960, appeared Berg's paper "On certain problems of cybernetics". Berg clearly proved that cybernetics was a progressive science, and elucidated the essence of common problems of control in living and nonliving nature, described ways of control of machinery and processes occurring when man exerts some influence on matter, human society, and living nature. In the article he brought out three avenues of further development of cybernetics: technical, humanitarian and theoretical. And, finally, Berg endeavoured to approach the important question of man-machine interaction. No mistics, no theorizing—just science and a sober approach to progress associated with cybernetics. Aksel Berg wrote: "The role of automation is to relieve man from manual labour, but the final outcome of new engineering and automation depends on how cleverly man puts them to use. Cybernetics, whose aim is to improve the efficiency of human activities in cases where he needs control, by no means excludes man with his knowledge, abilities, fantasy, experience and strivings. New technology improves the efficiency of human activities; mechanisms and automata serve man, not vice versa."

These utterances, now trivial and commonplace, were of importance at the time. They were opportune theses promoting cybernetics, robotics, and related fields, which had to

be given a boost to keep up with the latest developments, to repulse attacks on cybernetics, to put an end to mistreatment which manifested itself now and then despite the fact that common sense started to prevail.

An extended report "Cybernetics and scientific progress" delivered by Berg in 1962 at a session of the Academy of Sciences was a sort of account for the last three years and a programme of further activities of the Council.

Berg said in his report:

"When the Council for Cybernetics was established, voices of sceptics continued to be heard in the USSR. The fate of cybernetics in that respect resembles the fate of new ideas in quantum mechanics, relativity, and so on. But times change. The new always wins out and gains strength in struggles with the old. The dilemma here is clear: either ahead with the new and progressive, or to the dust-bin of history. This is said clearly in the new Programme of the Party, although in other words.

"I think that the strides made in recent years in the science of control are by no means incidental. It is time to deploy and develop the new science. This discovery was made in 1940s, and this should have taken place inevitably. Had it not been made by Wiener, it would have been made by somebody else. The problem of improvement of the quality of control of the fast-growing reserves of energy and matter emerged long ago, before the coming of the term 'cybernetics'. The appearance of the word, in essence, brought about nothing new, since it only described the developments that had accumulated, but were without their name. Long before cybernetics made its appearance man had to control complex processes in industry and actions of people organized into large collectives. True, this had been done with insufficient information and inadequate means. Therefore, the results in many cases were unsatisfactory, which was assigned to the influence of random or unfavourable factors. It is to Wiener's credit that he established the commonness of laws of control in living nature, in human society, and in industrial production. This opened a new leaf in the history of science. Cybernetics started a new life.

"...With the advent of cybernetics we started using the word 'information' in a new way. The fact that not all data, news and measurements are equally important was absolute-

ly clear long before this term started being widely used in science. The new thing here is only that scientists learned to measure this information and impart a numerical value to it. If this hadn't been done in communications, the developments in the field of computers would not be that impressive, since their principle is information processing. Now everybody understands that without adequate information, that is, without high-quality data arriving opportunely along different channels and complementing one another—consistent exact data—it is impossible to make decisions, and to effect control. Without accurate information about the work of factories, plants and other enterprises during the previous years, we cannot achieve a good planning of our economy for the future; without information about the sesources of fossil fuels and minerals we cannot plan the development of industry, and so on. Examples can be multiplied indefinitely. They illustrate just one thing: without adequate information there is no real progress.

"... We should remember that there are words 'progress' and 'stagnation', or 'regress'. Progress is purposeful and oriented. There can be no progress in general, this is nonsense. In our conditions progress in science and technology must be aimed at meeting ever growing needs of members of our society. Their needs should be studied on the basis of accumulated experience. In the language of science this means that we must have full-blooded information about the current situation in the country and must have at our disposal scientific methods and technical means to extrapolate this information to the future by preparing and processing it, and by working out scientific future outlooks concerning the needs of a communist society. It is absolutely necessary to apply methods of mathematical statistics, probability, queueing theory, optimal strategies (decisions) to find the best way of achieving an objective. Hence, cybernetics calls upon us to bring together disparate sciences, which is extremely expensive in terms of efforts and knowledge and is fraught with new difficulties. This frightens many and they try to hinder progress by maintaining that the venture with cybernetics is a luxury we cannot afford, that even without adequate information we have made strides in engineering and industry. Quite a dangerous conceit. If we have some achievements, they have been made not because we have done without full-blooded information,

and hence can do without it in future, but despite this. It is absolutely beyond doubt that if we had that information about the development of national economy, and if we had at our disposal techniques and means of its fast processing using electronic machines, our achievements would be much more impressive.

"Some decision-makers are still thinking that we can build communism by carrying out all the economic computations using dated technology, abacuses, which were progressive for merchants having no idea of multiplication tables. This is a great fallacy, and it is in disagreement with special decrees of the Government.

"However unusual and difficult it is for some conservatives who do not want to understand elementary things, we will construct communism on the basis of the widest use of electronic machines capable of processing enormous bulks of production, economic and biological information in the shortest time possible. These machines, called cybernetic machines, radically improve even in our time, and to a larger extent in the nearest future, the possibilities of making responsible decisions using adequate information. Grouped in computer centres, connected by automatic lines to production, transport and power industry, and agriculture, the computers of the nearest future will solve the problems of continuous and optimal planning and control.

"Now there is no more important problem than the fast development and wide introduction into the national economy of electron automatic means."

Berg went on to stress the importance and relevance of cybernetic method of control for a socialist state, with its planned economy. The problem is also of immense importance for capitalist countries. But in the capitalist world there is no total planning of economy on the national basis. And still major corporations find it profitable to have computer centres, which make their products more competitive.

But the important question arises of whether it is possible to control such a complicated and large national economy as the Soviet one? Perhaps it's a bit too much? Aren't random influences that affect the real course of events too many?—Berg anticipates budding doubts. There are no grounds for scepticism, one should not exaggerate the difficulties involved and lose faith in the strength of science. Statistics enables one to study processes in which

random forces are involved. One should only reasonably apply statistics to industrial problems. History of mankind abounds in examples of erroneous assessment of the potential of a man who undertook to govern a huge group of people.

Berg said:

"Springs to mind the analysis of the events on the Borodino field on 25 August 1812. On the one side, Napoleon, conceited and mesmerized by his powers and talents, on the other side Kutuzov, a decrepit ill aristocrat, personally brave and honest, but a man who has long lost faith in the possibility of a Commander-in-Chief to affect the course of events during a battle. To what extent, asked Tolstoy, both of them controlled the battle?"

Berg analyzes *War and Peace*:

According to historians, Napoleon spent the day of 25 August on horseback, reviewing the terrain, discussing plans submitted to him by his marshals, and personally gave orders to his generals. As a result, appeared the famous disposition. That disposition, written in a fairly unclear and tangled manner, contained four points—four orders. None of them could and was carried out. But the disposition said that on entering into action orders will be given corresponding to the movements of the enemy, and therefore one might imagine that during the battle Napoleon would give all the orders required. But this was not the case and could not be done because during the entire course of the battle Napoleon stayed away from it, and that (as it turned out later) the course of the battle could not be known to him and not a single of his orders during the battle could be obeyed.

Kutuzov from his long years of martial experience knew and with his old man's intelligence understood that one man cannot guide hundreds of thousands of men struggling with death, and, knowing that the outcome of a battle is decided not by orders of a Commander-in-Chief, not the terrain occupied by the troops, not the number of cannons and casualties, but that intangible force called the morale of the army, he watched that force and held it under his control, as far as it was possible.

Well, of course, Tolstoy exaggerates a bit, concluded Berg, both Napoleon and Kutuzov to a certain degree controlled the course of events, exactly to the degree to which

they were in possession of information and means of transmitting it. Even in critical situations they could still find means of bringing their orders to destination. But the analysis of the situation shows the philosophical concept of Tolstoy: everything is predetermined, one should resign oneself to the inevitable, not to resist even the evil. This viewpoint is totally unacceptable for us. The statement that complex processes are uncontrollable is congenial to Tolstoy's views. Just as there are no incognoscible phenomena, but there are only those that has not yet been cognized, so there are no uncontrollable industrial processes, there is only a difference between the complexity of a problem at hand and techniques and means of solving it. Cybernetics extends the sphere of controllable processes. It can help control vital functions in living nature, the labour of organized teams of people and man-machine interactions.

... This was just one of the many addresses of Berg, who understood that it was first of all necessary to explain clearly to the public what cybernetics was. And only then one can expect an influx of people into that sphere, only in that way it was possible to defeat those who thrive owing to the lack of real information about the essence and task of cybernetics.

Berg appeared much at scientific conferences, journalistic disputes, in student audiences, publicized the potentiality of the new science of control and kept saying:

"After a while we will create the world's best computer technology. We will build communism widely using cybernetic machines. Connected with production, transport, power and agriculture, computers will provide the most advanced planning of the national economy and fail-proof control of it."

Why isn't it Golem?

When Soviet cyberneticists were no longer wasting time and efforts on empty disputes and concentrated on their direct concerns, their darlings, cybernetic machines, began making enormous strides.

The electronic machines were becoming more "conscious", more "intelligent". And now they were accepted not as unskilled hands, but sometimes as advisers.

During a short period of time they passed through three

machine civilizations. At first they were applied to control only those devices and processes, the behavior of which had been fully studied and optimal regimes of control devised. Computers of that generation did not differ much from old-time classic regulators, maintaining a process in question at a predetermined level or varying it according to a specified law. And they did not care when something went wrong in an object controlled: some component broke (in a machine tool, say), the quality of fuel changed (in a furnace for producing glass, steel, etc.). They just could not "twig" that now they should act otherwise than specified. Therefore, under complicated or emergency conditions a computer, following blindly a specified program, was a mediocre controller. It only remained a disciplined executor, incapable of any creative activity. One of the forms of the robot pilot may serve as an example.

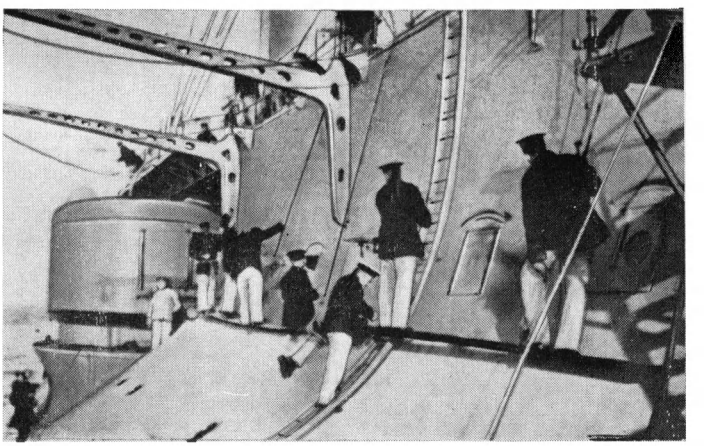
During a test flight the designer and a pilot were present on the pilot's deck, just in case. Everything went perfect, but they had to land eventually not where they had planned: the plane got iced up. Instead of just changing the operational mode of the engines, the robot kept sticking to the pre-set program, in which the icing contingency had been overlooked. And so the fuel ran out. But had the automaton been able to adapt to the changed conditions and affect the mode accordingly, the plane would have reached its destination. That was the first machine civilization, sort of a stone age for computers.

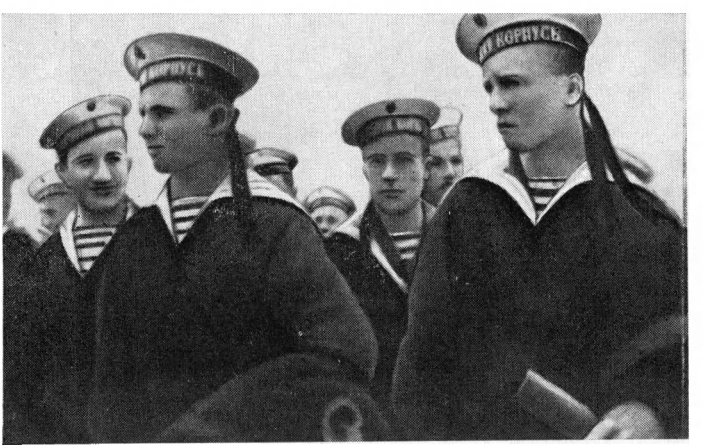
Then, machines learned to control objects, the behaviour of which could be described mathematically, but the best control modes were unknown. Now they were behaving as intelligent creatures, capable of comparing, analyzing and "twigging".

Lastly, came the third civilization, when scientists attempted to utilize computers in cases where both the laws governing the behaviour of an object and the ways of controlling it were unknown. Strange as it may seem, such a process appeared to be the cast iron production. The process could not be described mathematically. The secrets of the spluttering blast furnace remain unravelled so far. Therefore, it was impossible to pre-set an exhaustive program for a controller. And then it was decided to follow another path.

The computer was fed only with an approximate pro-

Cadets of the Naval Corps
on a training cruise





Mother, future wife
and sisters
(from right to left)
see Aksel Berg off on his
first training cruise

Nora Betlingk

gram, one that considered the principal, fairly known laws governing the process. But, while all the measuring devices providing information about the course of the process were connected to the computer, actuators were not. It may well be asked: how did such a computer function if it was not connected directly to the controlling organs? It only "saw" but could not interfere. In fact, the computer was at first not to control, but only to learn.

During the teaching period the controlling organs of the machines were operated by a skilled operator. Even unaware of all the laws governing the process or having a smattering of them, he controlled it from his many years of experience. A good operator compensates the lack of knowledge by experience and intuition.

What was the computer doing then? Having received data on the process from the measuring devices, it performed calculations according to the program. It compared the results of its computations, performed to find the setting of controls, with the operator's performance. Basing on the data of the comparison the program was changed, and in certain cases the computer itself adjusted the program to minimize the difference between the predicted position of controlling elements and that set up by the operator.

By gradually refining and complementing the program and eliminating relevant defects, the computer managed to achieve a sufficiently complete coincidence of predictions with the manually set positions of controls. Thus, the skilled operator taught the computer. After that training course the computer successfully replaced its teacher and later on was working completely on its own.

This proved that the potentialities of cybernetic machines, if not unbounded, were far from being used completely. Much depended on the program, and hence on programmers, their art and ability to utilize flexibly the potentialities of the computer and to break a problem down into elements so that the computer would have only to process it at a prodigious speed in its artificial brain. But where was one to get those programmers?

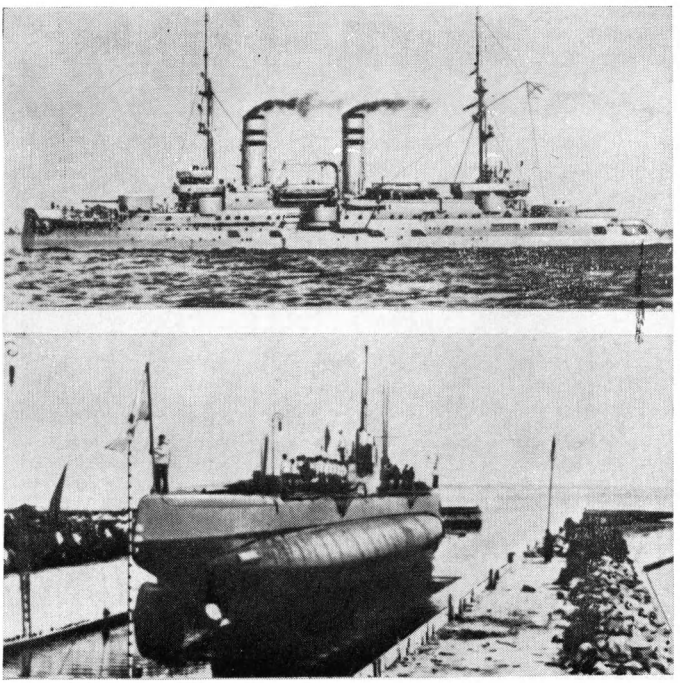
In those years programmers were a sore point. Few knew what training was necessary for them. Berg undertook some attempts to establish programming courses and departments. In the Council heated disputes went on—what had a programmer to be: a mathematician, logician or some

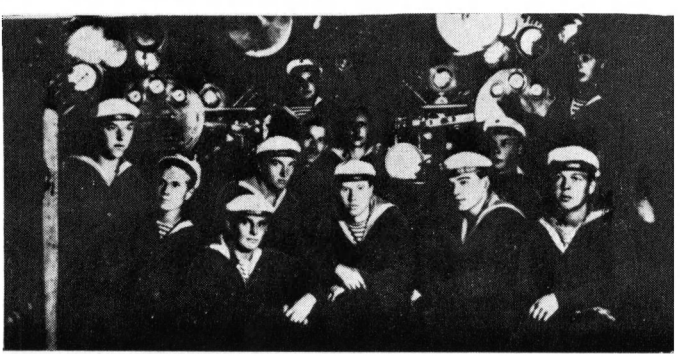
In 1914

The warship *Tsesarevich*

The submarine leaves
the dock

The crew of the *Zmeya*

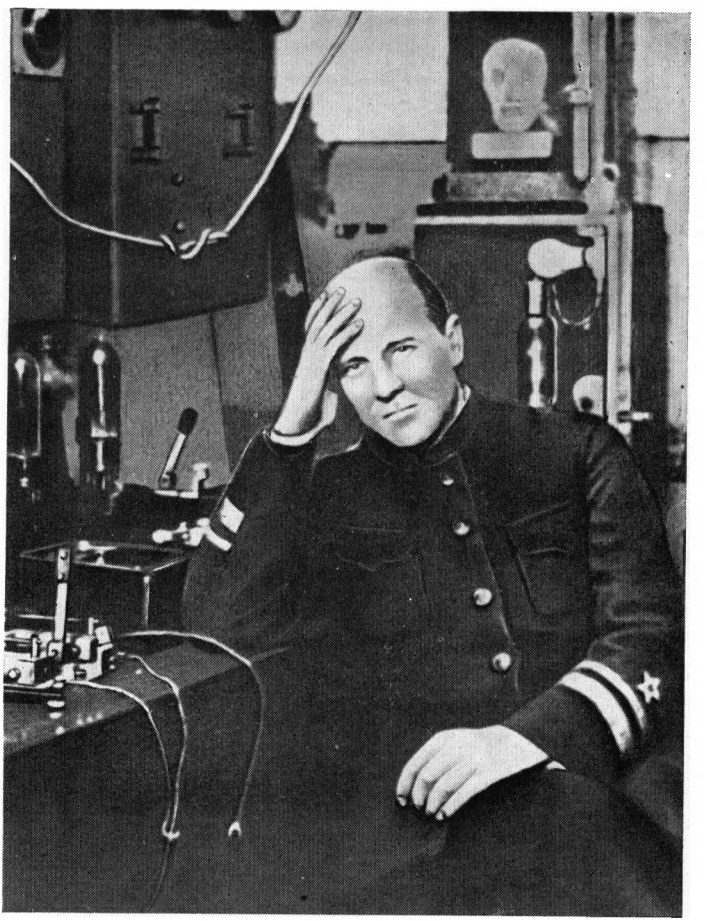




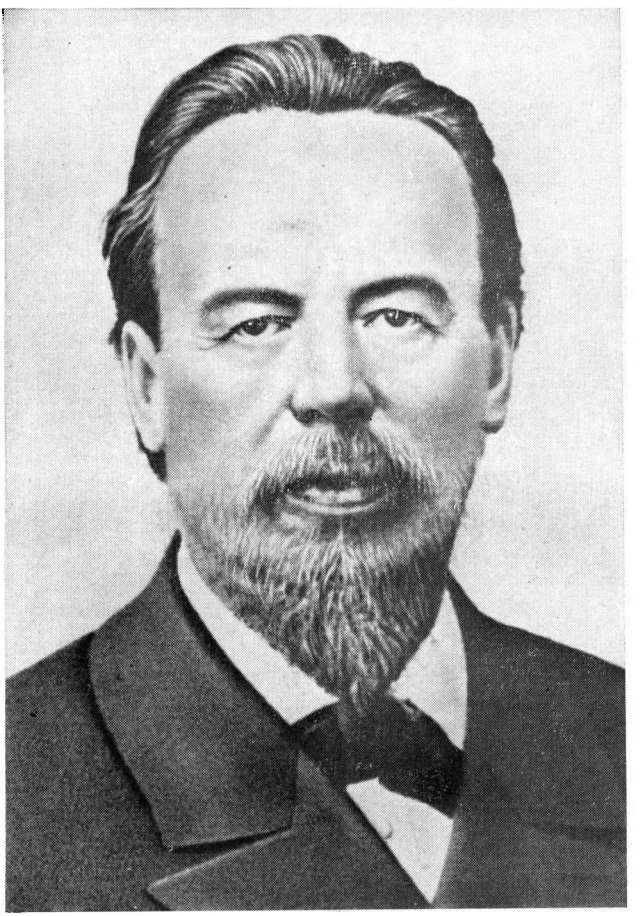
Alexander Fridman

Academy student Berg
at the radio laboratory
(1924)

Berg in a laboratory
of the Academy



Alexander Popov



other specialist? Only at first the computer was given purely mathematical problems. When some thought was given to, say, computer translation, it became clear that programmers must be linguists. When people started experimenting with computer diagnostics, computer programs were compiled by physicians, and then psychologists, teachers, and even experienced shop headmen, assisted, of course, by programmers.

Berg invited to the Council mathematicians to tackle the theory of programming and simple techniques of producing the most complex program possible. The task was posed in a rigid way—to work out methods accessible for people with only an elementary knowledge of mathematics.

It seemed at first that it was really impossible to compile a program without mathematicians. That view followed from the conviction that computers could only tackle problems obeying the laws of mathematical logic, that is, rigorous mathematical rules. And such problems are expressed in terms of elementary logical combinations and simple arithmetic operations. It took the designers some time to understand that computers could be taught in the course of work. That they should not necessarily follow a pre-established program, they can change it from their own experience.

Producing programs capable of adapting in the course of work, scientists learned to utilize control computers even when a process at hand had not yet been studied mathematically and no exhaustive program was possible.

A computer program appeared to be able to provide for an estimation of the future behaviour of the object. To this end, the computer has to go over several forms of behaviour for various possible changes within the system and in the environment. After having obtained results and assessed them by a pre-set criterion (for example, minimal fuel consumption or product quality), the control computer chooses the best variant. The computer sort of adapts to the variable conditions. It remembers the best control procedure, gains experience and knowledge, that is, acts as a human being. Again, like a man, it acquires with time features of a "self-adjusting", "self-organizing" system.

By creating programs that provide for self-organization and adaptation of computers, cyberneticists thereby extend the potentialities of electronic computers beyond formal lo-

gic and enable the computer itself to find a course of actions the operator cannot indicate for it specifically.

At about that time the well-known German cyberneticist K. Steinbuch wrote: "In the USSR the privileged position of cybernetics has been stipulated in the Programme of the CPSU. Business-like activity reigns there. This activity manifests itself both through wide popularization of cybernetic concepts among population, and through establishing large research institutes in Moscow, Kiev and Novosibirsk."

Chapter Two

The White Queen Left Its Place

A First Duel

Reports about advances of Soveit cybernetic machines were no longer accepted as morbid sensation. Computers become commonplace. But they continued to amaze people—they had many tricks up their sleeve. And so the day came when a Soviet cybernetic machine challenged its rival from beyond the ocean. Newspapers throughout the world flashed headlines: "Computers contesting". This heralded the first international match of chess computers in the history of the game of chess. Or rather it was not a match of computers themselves, but a match of sophisticated programs produced by mathematicians. The Soviet Union was represented by a program worked out at the Institute of Theoretical and Experimental Physics. The colours of the United States of America were defended by a program produced by mathematicians of Stanford University.

The Soviet computer chess player was much younger than its American colleague. When it was in its "nappies", I once watched its performance, which was improving literally before your eyes. At first its strategy and art were nothing to write about. Its memory only carried the main rules of the game, a couple of tactical laws, and, what was the main thing, ways of improving the tactics as a basis for its teaching in the process of game.

And then the computer started self-improving and widening its scope. For it to be able to analyze the game, improve its performance, change its style, and so forth, the program was compiled so as to take into account the previous games and instructions from outside.

Four games were played simultaneously. In the first and third ones the Soviet program was White, and in the second and fourth, Black. Moves were cabled.

Grandmaster Bronstein commented that unusual match thus:

"The games proceed in full accordance with the classical laws of the science of chess.

1st game	(1) e4, e5	(2) Nc3, Kc6	(3) Nf3
2nd game	(1) e4, Kf6	(2) e5, Kd5	(3) Nf3, e6
3rd game	(1) e4, e5	(2) Nf3, Kc6	(3) Nc3
4th game	(1) e4, Kf6	(2) e5, Kd5	(3) Nf3, Kb4

In the first game we see the beginnings of the four-knight opening. A curious transformation took place here. The second move of the white side meant a Vienna game, and the third move of White directed the game along the lines of the four-knight opening. If Black Knight comes to f6, we shall have a 100-per cent four-knight opening. So far the 'players' are doing according to the program, where the main thing is high reliability. In tournaments human grandmasters elect that opening in those rare cases where they wish to be dead sure that the game ended in a draw. The same is true of the third game.

"Second game. Here the Soviet computer chose an involved opening that cut both ways—the Alekhin defense. The idea behind Knight move is to lure the opponent's Pawn away from its own camp, so that then to launch a decisive offensive. So far the struggle follows chess theory closely, perhaps only in practice the third move is often d7-d6. A glance at the situation on the board in the fourth game shows easily why the program deviates from the theory: it seems to contain elements of acute attacking style, in the manner of M. Tal. The third move, with Knight, seems to count on Queen leaving her place, thus enabling Black Knight to take the c2 Pawn and to fork King and Rook.

"The 'home' analysis carried out by our computer indicated that for the positions in the first and third games the best move for Black is (3) Bf8-c5 with equal game. In the second game our machine, Black, deems that the strongest move for White is the aggressive passade (4) c2-c4 and believes, with good reason, that in terms of position White have the upper hand. However, upon further consideration the computer decided that a yet stronger move for White is the quiet (4) d2-d4. In the fourth game, where our computer has 'enriched' chess theory by its third move Nd5-b4, it considers that the most reasonable White's move is (4) c2-c3. The match is on. The next move is that of the Stanford player."

The match was won by the Soviet program.

This unique tournament stirred up much discussion. It struck all, but opinions differed. Some went into raptures, others shrugged their shoulders and grumbled, "Waste of money". Yet others tried to grasp, within their capabilities, the gist of the matter. But initially, as is so often the case, the fashion was set by the "overcautious". "Why should one teach a computer to play chess, who needs it? It's only a folly, expensive extravagance." By the way, something of the sort was to be heard once about cybernetic "turtles", "mice", and "foxes".

But those "pranks", it appeared, have deep roots. Chess is a clever game, it is not only a good pastime but also a good means for training intellect. The Spanish thinker Juan Huarte wrote: "The inventor of the game of chess created a model of martial art, because the game represents all the military moves and plans."

And by creating chess program scientists, in effect, produce models of programs of strategy and tactics, heuristic programs, that is, programs of creative activity.

The Council for Cybernetics stimulated extensive research in heuristic programming and search for ways of teaching a computer creative ways of "thinking". Those studies pursued one important aim. The functioning of such a computer might shed some light on the laws of creative activity. For centuries man has been improving his mental work, but up until the present time he has gained no insight into the basic principles underlying creative activity. The experience gained with teaching computers will allow us to work out more effective methods of thinking, and, what is exceedingly important today, will help us solve problems of teaching man more effective techniques.

"This is of immense importance. Take a closer look at a chess program", said Berg, "you'll discern in it the beginnings of that new computer about which instructors are thinking now. It has some features of a teaching machine capable of adapting to its student. What does a computer chess player do? It analyzes the moves of the opponent. Depending on the last move it each time follows a new path. And the teaching computer? Depending on the question of the student, it reviews its program, seeking to respond in accordance with the needs of the person who asked the question. It flexibly changes its answers and offers the student one teaching program or another. By processing

chess program we come a step closer to the production of intelligent teaching programs, so that without burdening the memory of the computer with a large bulk of information to enable it to come up with a wide variety of plans of action proceeding from a limited amount of information."

Yes, the chess computer cannot exhaust all the possible variants of answers to the opponent's move. There are more of them than there are stars in the Universe. The computer must choose a continuation only on the basis of reasonable variants, discarding unpromising ones. That is, it must "think". The same is true of teaching programs of self-adjusting computers, which are to become commonplace in our school to-morrow.

Who is More Intelligent!

The world was impressed by two achievements: the computer-assisted decoding of the mysterious lettering of Maya by the mathematicians at the Siberian Branch of the USSR Academy of Sciences (their results nearly completely coincided with those arrived at by other techniques), and the reading computer of the Institute of Automatics and Telemechanics. The latter computer, having mastered print, progressed to manuscripts. The program was worked out assuming that a letter written by different people has something in common, that any forms of "a" are closer to one another than to any form of "b" or any other letter.

That approach proved to be promising. In early experiments a computer fitted with a device for observation (sort of a TV transmitting camera), was shown a number of hand written letters or digits. The computer was programmed so that it identified signs common for a given letter or digit. After a short teaching period the computer could recognize without fail those characters among a sea of letters and digits supplied to it arbitrarily.

True, modern computers, despite their formidable memories and speeds take too long to read a hand-written text. Computer reading of manuscripts, which would allow us to do without typewriters, is a thing of the future, when the on-line memory and speed will increase ten- or even hundred-fold.

Once, protecting themselves from attacks, cyberneticists made a point of stressing in their lectures and books that a

computer can only accomplish what a man loaded into it, but it is unable to discover anything new, since it is programmed by man. At the time they did not yet take into account the dialectics of the computer teaching process.

The reading computer did not remember all the forms of writing a letter. It was loaded with a program enabling it to bring out the common feature in a given multitude of images supplied for its teaching. But the choice was done by the machine itself. This proves once again that a computer does not always need a rigid scenario, it is only sufficient to provide rules to be followed in various, often unpredictable situations.

To be sure, having no idea of what future has in store the designer cannot predict which decisions the computer will make taught by his program.

"Hence a computer may be cleverer than man?" sceptics raised their heads, "and man is destined to become a slave of the machine?"

Well, one should not be too strict about the sceptics—it is a difficult question.

Really, can it be said that a machine is more intelligent than man?

The British scientist John Bernal said that without intelligent men electronic machines are stupid, they even do not know when they are doing a stupid thing. If you produce a stupid program, the machine will yield rubbish.

And he goes on to furnish a funny example.

In the USA an electronic brain was created to answer when a war would come. All the data required had been thoroughly included into the program and supplied into the computer memory. The answer was:

"Yes."

"What 'yes'?" the programmers and their Pentagon customers were amazed.

The program was revised and reentered into the computer:

The new answer was more "exhaustive".

"Yes, sir."

You see, not all mental powers should be amplified.

By the way, during the early stages of the Korean conflict newspapers reported that electronic machines had been used to answer the question whether it was advisable to attack China. The computer vetoed the project. To what ex-

tent were those reports plausible? There is no telling. What is important here is that it may be truth, and horrible truth at that, if programs for intelligent machines are created by cruel and short-sighted politicians.

And still, what degree of complexity can be reached in an electronic brain? How close can it be brought to the powers of the living brain? One scientist assures:

"If we had enough modules (elements of the artificial brain) and they were sufficiently small and reliable, and lastly, we had enough time to assemble them, we would produce robots functioning following any specified program. It would not be difficult then to construct a robot behaving exactly like a John or a Peter, or one having any improvement upon their behaviour."

Another expert objects:

"Well and good, but what for? Do we need a robot taking after one man or another? A machine will never substitute for not only Newtons and Galileos but even ordinary people. Why all that colossal work, if from the very beginning we are aware of its uselessness?"

A third one volunteers:

"A computer close to the brain in richness of elements and connections would have to be housed in a building larger than the largest skyscraper. And to supply it with power would take the energy of Niagara falls, and to cool it, another Niagara. The number of nerve cells in a man is given by a ten-digit number, which exceeds by far the number of elements in the largest known computer."

Each new achievement of cybernetic machines again and again poses the same question: to what extent is the artificial brain perfect? To what extent may it be called "thinking"? The British computer scientist Turing suggested that a machine can think if under some prescribed conditions it can imitate man in answers to questions so well that it is able to deceive for some time the man asking questions.

He invented the following rules for that peculiar game. A human examiner and an unseen subject exchange questions and answers. If in a while the examiner fails to form a pretty good idea as to who his companion is—a man or a machine—he gives up. And then Turing recognized the right of that automaton to be considered thinking.

Another scientist maintained that he would put the sign

of equality between man and machine, if the latter can be taught to laugh at a joke. But since not all of his colleagues laughed at that definition, there was no discussion about whether or not a machine must have sense of humour and would it pay to spend millions on supplying the machine with that sense.

These discussions at times resemble the 17th-century disputes about where the entrance to nether world is to be found. Even now there are many opinions and many heated disputes as to whether a machine can be more intelligent than man. And it is only natural—men of science keep amazing at the ingenuity of nature, which managed to "pack" the small volume of the human skull with so many possibilities. Not only at the fact that the number of adaptable elements of the brain is larger by far than in the largest computer, but also at the fact that the nervous system features the unique power of compensating for lost functions. Some minor injuries do not lead to the failure of the entire system. In engineering there is nothing of the sort so far. But engineers keep looking for systems able to perform their duties despite damages to individual elements.

As for the question of who is more intelligent, it is hardly reasonable to confine oneself to a formal answer.

The present state-of-the-art makes it possible to obtain in the computer memory such a capacious vocabulary and to give it such a program that the computer would compile a complete set of answers to all the questions possible.

But, according to Einstein:

"Whatever a machine could do, it would be able to solve any problem but would never be able to formulate at least one."

Berg develops the idea:

"It cannot even desire to do this, a machine has no thirst for knowledge. An artificial brain cannot go beyond the framework of predetermination. A machine is unable to invent and to get interested in anything. It's beyond its capabilities not by virtue of inadequacies of engineering arts, but by virtue of its impossibility in principle. And we, scientists, are not scared by this. We know that the laws of thermodynamics preclude perpetual motion. Heisenberg's uncertainty principle states that it is impossible to accurately determine simultaneously both position and velocity of

a particle. Einstein's theory of relativity states that it is impossible to move faster than the speed of light in a vacuum. There are prohibitions which man may not violate. He cannot erase the demarkation line between man and machine, between the living and the nonliving, and is it really necessary to do this?"

"Formulation of problems, true creativity is a need of human mind. Machines, however, help us in solving these problems and even indicate a correct and fast path to their solution, and this is not little. This once more stresses the legitimacy of works on amplifiers of human powers."

Bit by bit the aura of "diabolic suggestion" fell down from the amplifiers of mental powers, and they appeared before the eyes of recent sceptics in their right guise, as machines. Machines that were taking over some of the human concerns.

Man—Machine

The Council for Cybernetics has been in existence for many years now. It has sponsored dozens of conferences, seminars and schools, published thousands of papers, hundreds of books on a wide variety of aspects of cybernetics, and the Council proceedings kept accumulating on Berg's bookshelves. Among them *Problematic Notes* and section reports. These are annual reports submitted by the sections. "At last came out *Problematic Notes* of the 16 sections of the Council for Cybernetics," wrote Berg to me, "I send a complete set to you. This is a huge work of the Council. We have sent out the *Notes* to all the addresses concerned and requested them to send us reviews, additions or corrections. Next we will publish them with amendments once more. I regard this work as being of great importance—it reflects all our advances, all our needs and the spectrum of research in cybernetics."

Leafing through these tomes gives one an idea of what a diversified network of problems concerned the Council. Since its first years cybernetics tied into a tight knot disparate spheres of human activity, clashed interests, interwove needs and combined technical means—this at times seems just unbelievable. What do law and mathematics, bionics and semiotics, human organs and the pendulum of a clock have in common?

They, however, are links of the same chain. *Problematic Notes* show this clearly and convincingly. They cover mathematical aspects of cybernetics and reliability, transport management and cybernetic aspects of chemistry, psychology, economics, law, and general management. And each of these problems is further subdivided into specific topics going down to practical problems of science, engineering, and life.

Some of the names of new sciences sound unusual. Take human engineering, for example. I am an engineer but I do not quite understand why the word "human" added to engineering makes it into a new branch of science. And what has cybernetics to do with it?

It turns out that human engineering is a discipline devoted mainly to man—machine systems. This is going to be the main problem of the future, because machine is coming into ever more close contacts with man in complicated production and household situations.

This is characteristic of all fast processes, where man is not fast enough to cope, where he does not show adequate "throughput", that is, is unable to process the incoming flux of information.

Being a military man, Berg had an especially clear picture of the complexity of modern warfare. A man controlling a modern fight is in no position to grasp in its totality the quick-changing situation on the battlefield (changes in the number of troops and armaments involved, unexpected manoeuvres of the enemy) so that to take correct and opportune measures. This is especially so in the case of a pilot involved in a dogfight.

These days aircraft fly faster than sound, and missiles' speeds are called "escape" and "orbiting" speeds not for nothing. The responses of the airman become the main snag of nature's making. The human pilot cannot cope with the kaleidoscope of the situation, he has no time for thinking, correlating and analyzing. He just cannot carry out all the necessary calculations to select the best move. Here, of course, a fast-speed computer is at a premium, it can not only take in all the information, but can automatically pilot the plane. This machine must be faster than man, and by no means less intelligent.

And where man cannot be replaced, he must be given

a sound training on earth to prepare him for those situations which may occur in the air or in space.

But it appears that in the training it is not sufficient just to control the responses of an airman or an astronaut to readings of dials and controls. The training must be based on the findings of the science dealing with the functions of the entire man—machine system. And human candidates must be carefully screened—not anyone is able to carry out one or another task. Professional tests are an extremely important thing. True, they were too much in vogue at one time, and sometimes they were carried out without due account of the latest findings of sciences. Tasks offered to claimants for the modest post of a shopman or a book-keeper invited much ridicule.

But adequate scientific tests give a reliable indication of inclinations for mathematics, physics, humanities and other pursuits. They permit a correct selection of people suitable for a particular occupation. Therefore, among other topics covered by Berg's Council were "Automatic tests for measurements of the higher nervous activity", "Gauging the general intellectual level", "Reliability of the brain", "Operator fitness control".

"And still," stated Berg, "having handpicked persons most suitable for the career as an astronaut, and even given them an adequate training, one cannot avoid a difficulty that stems from the fact that the human brain is inherently adapted to ground, not to space. The first couple of decades an airman spent on solid ground, his forbears have been earth-bound, and his brain is by inheritance oriented on the main task to help him feel at home on earth. Therefore, all the organs feeding the brain with information from the surrounding world have also evolved throughout eons and got used to serving the brain in a definite, customary environment. And now man stepped into space, and went down into the deep of the ocean. He has thus transferred his activities into a foreign medium. The brain cannot handle its tasks in that unknown and biologically unsuitable environment, and our senses often fail to respond to external stimuli. Everything occurs as if a man would suddenly appear in the dark."

Really, we got used to living in the light, and the eye supplies visual information to the brain, so enabling us to tell a closed door from an open one. In the dark we are as

uneasy as a bat in the light. The bat's sensory organs have evolved so that they got adapted to the life in the dark. The bat has developed a kind of ultrasonic "radar", which renders all the obstacles visible to the animal. If we were possessors of such a radar, we too would be able to feel absolutely at home in the dark.

But man has no senses responding to magnetic and electric fields, ultrasound and radio waves.

And so cyberneticists set out to invent the most rational ways to remedy that "mistake" of nature. Perhaps man should be equipped with artificial senses he lacks, using devices, transforming information not perceived directly into optical, sound or other signals? Or maybe man should be completely freed from participation in complex and dangerous experiments and automata would do the job.

The same question presents itself in other domains:

"In industry, strange as it may be, man sometimes is a 'bottleneck'," related Berg. A failure at a power station disturbs normal functioning of entire industrial regions, lights go out in dwellings, and electrical transport stops. Not infrequently one failure entails another. Fresh in our memory is the huge failure of the power supply system that for a long time paralized the life in New York and nearby regions of the eastern coast of the USA. Even the most experienced operator is unable to grasp immediately a situation and make a correct decision. He needs time, which, of course, depends both on his experience and hardware at his disposal. A failure may propagate like an avalanche, and in these conditions only a computer in a split second can take into account all the facets of an event, go over several scenarios of remedy, choose the best of them, and then realize it.

It goes without saying that without an electronic system of collection and processing of economic information we cannot make full use of a planned economy—Berg made a point of this. And our task is one with so many unknowns, with such a dynamics of initial data, that in complexity it is only equal to the cosmogonic problems. Data from all enterprises flow together in planning offices. This is a powerful flow of information about materials required for factories, about costs, and depreciation; about subcontractor supplies, and so on and so forth. This all has to be taken into account and a plan has to be worked out such that

would yield the maximal economic output. Planning is essentially a cumbersome statistical and computational work, which is only up to a computer.

But at the input, output or somewhere in between, comes in man. Things become complicated, and malfunctions occur. Problems arise exactly as a result of inadequate man—machine interaction. Problems of intercourse, of translation of a computer language into a common one, of understanding, of matching possibilities, of responses of man and machine. The level of man—machine intercourse, that is, the easiness and quickness, reliability and faultlessness of their interaction, predetermines the quality of computer-assisted control.

The Council for Cybernetics, providing guidance for human engineering studies, considered the entire man—machine chain starting with the conceptual design of the machine. And this initial stage was the most tantalizing stage, it was a subject of especially heated disputes. Here there was an infinite diversity of opinions. The leader had to form his own judgement and pronounce decisive word, but how difficult it was sometimes to say it!

Suppose that the purpose of a future machine is clear. And now comes the agony of selecting a concept. What idea should be laid at the foundation of the machine? One way is to shape it after the manner of human being, that is, to teach it to act as a man would act. Of course, if it is known how a similar problem is solved by man. But this is not always clear. How, for example, do muscles generate energy? It is unknown. Although this is a generator with the highest efficiency known in nature. How do our eyes recognize familiar people and things, and distinguish them among thousands of others? How does our hearing recognize a familiar voice, our nose distinguish smells?

If we succeed in teaching a machine all this, our life will transform radically. Our helpers will be machines controlling traffic and spacecraft, performing scientific observations, sorting out post, goods and papers. Ideal gear for the blind will be developed, which will transform ordinary letters into sounds perceived by the ear. It will be possible to get a subscriber on the phone not by dialing but by voice. Commands will be given to a machine not via a complicated system of digital codes or punch cards, but orally, using an automatic translator.

All this could be realized readily, should nature disclose to us its secrets of recognition of visual and sound images. And this will happen, sooner or later. We will introduce into an automatic device a hand written or printed text and the machine will review it. An automaton will recognize oral speech, make a precis of a meeting or interpret for us.

But so far the path to these possibilities lies through a wide stretch of terra incognita. Frequently scientists can with more ease put forward a novel principle of an automaton or write a new program than to imitate the human organism. And still when a translating computer was designed, the people first of all tried to imagine how a human translator goes about his business. With a pattern recognition machine designers tried to find out how the human brain does the task. When designing a self-taught, self-perfected machine engineers proceed from their idea of human perfection. And so things often boil down to problems that baffle by their insolvability: how has a human organism evolved into such a complete system in perfect harmony with the surrounding world and with perfect self-adjustment? Why has nature produced this organism, not that? How are the various organs developing within an organism; why does it grow to some limit and then the growth ceases—the organism has reached maturity and completeness inherent in that organism. And what is the limit of perfection of a machine? And how will a machine know about this when it is engaged to construct another machine?

This gives rise to a host of engineering and philosophical problems.

"Unfortunately", said Berg, "nature does not let the cat out of the bag, and we cannot teach a machine to work according to the same principle as nature makes man follow. The most important thing here is to find the principle of the machine that would be as close to the ideal as possible. Therefore, scientists experiment with so many models of cybernetic devices that imitate the requisite features of human psychology and nervous system. And err, of course, now and then—to err is human."

Fortunately, the first stage of cybernetics, when were made brave, dizzy, although often ill-considered, comparisons and conclusions, passed. And so did the familiar attitude to the notion of "thinking"—a sore point of many

workers. Although they did not think, like Lucretius, that the process of thinking is a motion of tiny round atoms, much faster than others, heavy and sluggish atoms of matter, but still they were quick with promises of nearly any model of mental activities. So they predicted the forthcoming arrival on the scene of thinking automata, which allegedly could replace man completely. Now it has been understood that the man—machine problem is much more involved and dramatic than it might appear on the surface.

The time has come now of more serious developments, of more meticulous and profound insights. This manifests itself in the evolution of the contents of *Problematic Notes*. Reading them clearly shows that cybernetics has undergone a qualitative change. Earlier days saw only individual discoveries, some lights in the darkness here and there. Later on everything merged into a stream. Cybernetics became a science and what earlier was just intuitive insight now got to be carefully planned. Now theory paves the way for discoveries in cybernetics almost as in physics—by planning possible experiments and processing their results. Theory and experiment prove the feasibility and necessity of development of one machine or another, compute and test its principles.

Chaos was replaced by order.

This ordering was the major concern of the Council for Cybernetics as a whole. The Council united those who did cybernetics. They were active workers in research institutes and plants. A thread connecting a finished computer with its initial concept, experiment with theory, drew from the Council through its members to scientific laboratories and enterprises.

On Teleinfection

Berg paid much attention to the section "Cybernetics in life sciences". It will be recalled that psychology proceeds from the Pavlovian statement that the human organism on the whole is "a machine unique in the context of our modern views, one with the highest level of self-regulation", and from this point of view the way of looking at man is about the same as at any other system. But medical scientists take a closer look at the problem. In addition to the general Pavlovian approach to the central nervous sys-

tem and its highest reaches, the cortex of cerebral hemispheres, that system of control of all the functions of the organism, they also look at the physiology, biology, and clinics of that most complicated machine. And cybernetics relies heavily on the advances in physiology. Here permanent contacts between living and nonliving nature occur. Science likes parallels, which caused much trouble in cybernetics. And some of this trouble, alas, was due to workers especially fond of it. Many went too far in pursuing the analogy between man and machine, thus lapsing into vulgarization, especially as regards the brain.

The section was concerned with four areas: physiological, medical, and biological cybernetics, and neurocybernetics. The studies used parallels extensively. Physiological cybernetics applied the concepts and techniques of cybernetics to physiology, including the uses of mathematical tools to process data on observed functioning of human organs, the uses of sophisticated computers for processing a sea of curves, diagrams, electrocardiograms, encephalograms in order to correlate various physiological tests.

Medical cybernetics used electronics in diagnostics and prognostication of the course of a disease. One breakthrough was the invention by Professor A. Kobrinsky of an artificial arm controlled by the biocurrents of the organism itself. The gimmick interested investigators and journalists. Some of the headlines read as follows: "A wonder of the 20th century", "A device controlled by will of a human being". That was a real eye-opener. And really, the artificial arm was controlled by the signals picked up from the skin near those muscles that in a good arm control the palm and fingers.

A man with a good hand wants to take a pencil and put down a word, and immediately his brain produces some nerve pulses initiating muscle reactions required in order to do the job. The brain of an invalid also generates the same command pulses, but he has no palm and can only hold a pencil using an artificial appliance. The command pulses cause contractions of the remains of appropriate muscles and appearance of biopotentials. It is these that control the artificial arm.

This artificial arm is, of course, a far cry from the earlier ones, which only made use of the physical energy of the remaining muscles. This is an electronic device power-

ed by a small battery. By day the arm is functioning and by night the battery is charged from the mains.

Repair operations in atomic power stations and laboratories are sometimes carried out using sophisticated mechanical manipulators, an involved tangle of swivels, levers and blocks. But how about replacing this arrangement by such an artificial arm? This would enable the operator to regulate most complicated processes like in a puppet-show.

The Council could hold with good reason: "The Commission for Biological Cybernetics coordinates research into control processes in living organisms, and applications of the ideas and techniques of cybernetics to studies of general biology". And: "The Commission for Neurocybernetics coordinates studies of the central nervous system as a control system for the functions of the organism. For one thing, these works make it possible to reveal the basic patterns of control of the functions of the organism; for the other, in certain cases they pave the way for engineering applications of the laws of living nature."

These are the above-mentioned parallels between the living and the nonliving, between man and machine. When did they become possible? What warrants them?

Investigators were accumulating experience, gleaning evidence concerning both organisms and mechanisms. And medicine made a stride, and so did electronics. Above all, at the interface of medicine and engineering people were looking for common laws. They did know that such laws existed and they searched for them. In this search it was important to formulate questions correctly. One prominent physicist recalled that he was much obliged to his mother. When he returned from school, she would ask him: "Have you asked your teacher serious questions today?"

Berg sought to make medicine omnipotent—what is more important for humanity? Health is the most valuable thing in our life.

And it was in medical cybernetics that Berg's contribution was especially notable. He cemented individual areas of research and helped to achieve a harmonious fusion of the potentials of various sciences. For the workers in life sciences his help was invaluable, without it they would long have stewed in their own juice, because it was extremely difficult to train workers who would be equally at

home in medicine, mathematics and electronics. It is necessary but it is a matter of the future.

It was perhaps for this reason that Academician Anokhin, a scientist of world renown, wrote to Berg:

"Your activities are too extensive and many-sided to be described in several telegraph lines. And our encounters contained much more than a dry telegram can convey. That is why I would like to concentrate on what I think is especially significant and useful in your noble activities of a champion of the new in science.

"Hardly anybody else could with such an audacity critically censure decrepit traditions by carefully introducing the findings of cybernetics and electronics virtually into all spheres of our life. I often hear bewildered questions of even intelligent people: What has planning to do with cybernetics, radio engineering, and electronics? They are all for machines, for industry.

"That in such nontechnical fields as, for example, planning, teaching, etc., people started to speak about and introduce the achievements of electronics is undoubtedly a result of your initiative, and vehement energy.

"You have raised the prestige of these new domains unbelievably. You have attracted the attention of the wide scientific community to the issues of cybernetics and electronics, and this is again a great contribution of yours.

"All Soviet investigators appreciate the provocative influence of your example for our young blood in science. Life sciences received the refreshing stream of physics, mathematics and electronics, and this is also a result of your vigorous promotion and grandiose organizational activity.

"And perhaps of no less importance is your constant concern that reasonable proportions be maintained in the natural striving of our scientists, especially the younger ones, to exact, mathematized knowledge and modelling of involved phenomena of life. You keep stressing that the creative potential of the human brain should not be wasted.

"I remember how once my teacher I. Pavlov, within a narrow circle of his disciples, commenting on the eccentricities of once famous Prince of Oldenburg, said: 'I recognize only one form of aristocracy—the aristocracy of intellect.' I have always been holding in high esteem precisely your care for the creative resources of the human

brain, for its inexhaustible potentialities to produce new and large creative arrays unbounded in space and time.

"I am happy that I have been meeting you during our discussions of neurocybernetics, a problem of mutual interest for us.

"And although we are seeing less of each other lately (hopefully, I have not got into the 'anticybernetics' folder), I always remain captivated by your energy and enthusiasm, your noble faith in the great new cause.

"Medical workers, both clinicists and theoreticians, will always be grateful to you for the fact that you, having scrapped the theory of 'natural' assimilation of the new, bravely and vehemently appealed to them to make use of the formidable potentialities of cybernetics and electronics.

"And there can be no doubt that your struggles, your personal example and enthusiasm exerted a most favourable influence on the Soviet life sciences.

"Dear Aksel Ivanovich, may you for many more years continue to develop that cause of immense importance for the country and to fire your colleagues with your inexhaustible energies and ardent enthusiasm.

"And I am confident that medical scientists, in spite of their professional inclinations, will not be against that noble sort of 'teleinfection', and that you have added a glorious page to the history of the new age of Soviet medicine and biology.

Sincerely Yours
P. Anokhin"

Chapter Three

Meeting on the Summit

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Roses and a Fish

Problematic Notes demonstrate close cooperation of the various sections. Bionics Section, for example, is concerned with living organisms with a view to introduce into engineering some principles of living nature, such as principles of motion, orientation, navigation, control, and biological reliability. It covers studies of the eye and the ear, and modelling of control systems as nervous networks, and studies of muscles as energy generators. The aim is to make use of the enormous experience of living nature.

It may well be that Berg had this in mind when he commented on anticybernetic papers: "Man has always found some practical aspect of knowledge—is it possible to put to work some laws and phenomena of animate nature?"

On 20 December 1965 at Moscow University Berg opened a conference on bionics. The assembly hall, sitting more than two thousand people, was overcrowded. Reports seemed to be equal only to narrow specialists, but the attendance stroke with its diversity. One could find there scientific journalists and military (I asked the test pilot Mark Gallay what brought him there, to such a specific meeting. His answer was: "the man—machine problem, the reliability of the human brain, tests for professional screening of pilots".). The conference attracted A. Kron, a playwright and novelist, a "pure" man of letters. What made him come there? It turned out that he was writing a play about biologists. And so Kron was sitting with a note-book in hand and listening attentively to reports: "Morphofunctional types of the skeleton of the pelvic girdle in mammals", "The various paces of the mammals as possible motions of lever machinery", "The theory of the buoyancy force in octopods", "Experiments on magnetic orientation of birds", "The role of gravitational waves in near-field orientation of fish", "The influence of magnetic fields on processes of teaching mice in a T-shaped maze", "An automaton model-

ling functions of forming motional habits in animals", "Prediction of the reliability of work of man—machine systems and heliogeomagnetic factors", etc., etc.

Quite recently science was only a business of investigators. And they were jealous of various intrusions, and now... A tower of Babel. People who had been concerned all their lifetimes exclusively with fish or birds, bats or apes, were involved in heated discussions with electrotechnicians, electronic experts and mathematicians. And they somehow managed to find a common language. Some (biologists) were relating about techniques of teaching birds, dolphins, apes; others (technicians) were contemplating ways of using this evidence in their studies. At first sight, what could be derived from a report about the variety of "languages" of birds (Canadian birds do not understand their French sisters; alarm signals recorded from birds of Mexica leave the birds of the same species in Australia totally unimpressed), or even from the impressive discovery of the secrets behind perennial migrations of fish to their spawning grounds.

Fish take their bearings from sea currents and this is coded in their genes (therefore even a young fish, which has never been to the spawning grounds, finds its way there without mistake), and birds are guided in their migrations by the geomagnetic field. Using these findings, engineers set out to work out more reliable navigational and other systems. Each report supported the revolutionary findings that there are common laws in animate and inanimate nature, similar control principles, and illustrated the fruitfulness of cybernetic approach to various phenomena of life and engineering.

Bionics is a field where zoologists, engineers, biologists and mathematicians joined their forces. Also contributing to it are people who are interested in electronic "thinking" machines with a view to get some clues to the patterns of thinking and mental activity.

Notes show that cybernetics penetrates fascinating unthought-of domains. The only thing required for it is quantifiable information, some data base. Information is the alpha and omega of cybernetics. Control is only possible when there is information about the object to be controlled, if only statistical data, the more reliable the better. Evidence may come from observations or specially staged expe-

riments. Berg was paying special attention to the collection of information.

"Human experience is inexhaustible", he used to stress in his talks, "in certain cases experience accumulates over the centuries, but since we were unable to store it, we have forgotten and lost much. One and the same discovery is often made several times, stale news are retailed by different generations. Mankind got used to wasting the most valuable product of civilization—information. And only now that computer memories keep growing and communications systems have embraced the world, can we in an absolutely new way and on an absolutely new qualitative level organize our economies, science, and life in general. In this day and age pieces of knowledge gained in various countries and in various spheres of human activity will not disappear in the sands of unreliable human memory. Need an example? There are lots of them. Take this letter, for instance". And Berg reads a letter from fishermen. We are grateful for the assistance you rendered to the State Production Committee for Fisheries in solving a number of questions concerned with the uses of cybernetic methods in fishing.' "Well, with medicine, biology and other sciences it is clear. But fish?"

Berg is glad to see the amazement of the audience, he laughs. A moment before he looked tired. But now his eyes again glitter with humour, he himself is surprised by the diversity of cybernetics, its power, its ability to come in handy in unbelievable situations.

"Imagine thousands of fishing boats," explains Berg, "scattered all over the world oceans: in the Indian Ocean, near Australia, in the Arctic waters or off the South America. It is impossible to have a rigid time-table of their movements, like that of trains. Catch is a matter of chance. It depends on weather, on the availability of fish. And what port should be called better to unload the catch is unknown as well. A boat calls some port and is in a hurry to dump the fish at a canning factory, but nobody was waiting for the boat there, and shortly before another boat came in and so the factory has its stores full of fish.

"And so the trawler, which has spent months at sea and is full to the brim with fish—it costs hundreds of thousands of roubles—now has to try another port. And the fish is pe-

rishable, and the trawler is wasting fuel and time. The loss is enormous. What is to be done?

"That is why fishermen applied to the Council for help. Cyberneticists advised them to organize their computer centre and to apply mathematical techniques to fishing.

"A couple of years passed. And now they have their own computer centre. From all the boats all over the world information flows in about the progress of fishing operations, the directions of movements, production at floating fish-canning factories. Computers quickly digest that huge information flow, analyze it, and yield recommendations to captains.

"And so in any field", concludes Berg, "until we have learned to make use of the previous experience, that most valuable 'archives' and all today's information, progress will be rather a matter of chance, not law."

Berg liked to state that the primary task of cybernetics is to extract useful information from that chaos of evidence that has accumulated in all fields of knowledge. The next step is to analyze and utilize that experience so that further search could be organized correctly.

Take chemistry, for example. What uses can be found for cybernetics in chemistry? But in the Council there is a chemistry section. Its field is a new discipline, mathematical chemistry. Its task is to optimize experimental design in chemistry and to derive useful information from contradictory results of the experiments.

Now before an industrial chemical plant is erected, its design is preliminarily checked on computers. A reaction is described mathematically and the computer selects chemical ingredients to work out the optimal kinetics of the future chemical reaction. A computer can simulate a chemical experiment, quickly, efficiently and inexpensively. Real chemical experiment may last hours or even days, the computer "conducts" it in a matter of seconds. A series of chemical experiments conducted in search of an optimal process may take years. The computer makes it in several hours. In such a way at the Novosibirsk chemical combine a computer-designed prototype plant was tested. The time lag since the beginning of laboratory studies to industrial production was only 3 years, not the normal 10-12 years. Most of the time went into manufacturing and mounting the apparatus.

For several years now the chemistry section has been holding workshops to retrain chemical cadre. Chemistry got really mathematized. Quite recently even the most shrewd of chemists were sceptical. Many were opposing the introduction of mathematics into chemistry. Now this is backed by the entire profession.

Strange as it may seem, conservatism is often displayed by those who ought to be at the frontiers of science. A man not associated with some narrow field of knowledge, but commanding a wide scope, has a way of showing more revolutionary attitudes to inveterate traditions. His advantage is that he has a fresh way of looking at things, he does not need to discard some habitual views. His thinking is not confined to traditional, common approach. That was why, perhaps, Berg managed sometimes to be more far-sighted than a narrow specialist. Especially with his formidable erudition and knowledge, and his stamina. He was not afraid of going back to the drawing board. He read, read, and read. Often he took up quite unexpected disciplines, and at such a high level that he was in position to provide guidance even to specialists. Take medicine, for example. He was among the first to stress that this field might benefit from electronics. Or geology, when in the Geology Committee before an audience of leading geologists he had to demonstrate the need for accurate account of all the geological evidence gleaned all over the country by expeditions and for computer processing of it. A similar situation once emerged at a furious run-in between mathematicians and jurists, and it was Berg who reconciled them.

A Surprise for Sherlock Holmes

Having got the wind that there were machines that, based on early experience, could predict future, jurists once decided to ask mathematicians to produce special programs that would help them to investigate crimes. An attempt was made to dissuade them:

"It's impossible. This is not a problem of mathematical logic. Law is not an exact science, it does not obey mathematical laws. Therefore, its elements cannot be computer programmed."

"Why impossible?" argued men of law, "You are behind the times. At the dawn of cybernetics the answer to the

question was really negative, and a computer could only control processes interpretable in mathematical terms. But now, as the saying goes, quantity has transformed into quality."

And the lawyers proceeded to furnish a scientific foundation for their request:

"Help us to make a program for investigations, if only for identifications of finger-prints. It is an important problem for us. Finger-prints may appear to be the only bit of evidence, the main link in the chain of investigation. There is no general file of finger-prints, and even if it existed, one would have to spend a prodigious amount of time and effort just to establish whether or not it contains the print in question. The computer, with its speed and capacious memory, is a must here. It would in seconds compare a finger-print with those stored in its memory and identify the print's owner."

But mathematicians threw cold water on the enthusiastic jurists:

"A computer cannot, like man, compare finger-prints. The problem of recognition of visual images by the computer has not yet been solved. Also, if one is to compare finger-prints as you suggest, this would not bring you too far. The process is very slow."

The jurists, in turn, informed the mathematicians that they had long abandoned the primitive, manual method. This would require complete collections of finger-prints in any town or would lead to waste of time in sending finger-prints to a central file. Now they describe the prints using a code, that is, a set of main elements of those involved patterns which mark each of us. Such descriptions can be cabled, and a computer can find out whether or not the description of a given print tallies with one of those available in the file. But the difficulty lies not in comparing the descriptions, but in teaching the computer to take over the most complicated and responsible job—the coding of prints.

"But this is not the whole of the story", continued the jurists, "it is not always that a criminal leaves his finger-prints. But there is another feature inherent in a given individuum only. This is the peculiar composition of sweat. It is as unique, as the finger-prints. So far only service dogs who have keen sense of smell use it. Will you please teach your computer to do this?"

Now the mathematicians got on the alert—the jurists were making the problem even more difficult. It was only recently that the computer was taught to read. And now they want it not only to "read" patterns but also to differentiate smells. Again this boils down to image recognition, but chemical image now, a more complicated task.

"But maybe your machine can compare photographs?" the jurists added fuel to the flame.

"Don't you understand that this is an insolvable problem," assured the mathematicians. "How can you unfailingly draw a conclusion about the identity or difference of looks of a man, if you compare pictures taken in youth and in declining years. Some features remain, others disappear over the years, and yet others develop anew. A human criminologist can perceive this somehow, but a machine? How can you guarantee reliability of comparisons of pictures taken full face and in profile? Or another situation: a criminal has undergone a plastic operation. How are you to identify him from his photograph? This became extremely important in searches for military criminals."

"We answer these questions using a verbal portrait", explained the jurists. "A verbal portrait is a description of the appearance of a man compiled by a specialist who is able to highlight the principal, characteristic and spectacular features. A verbal portrait can be relayed using telegraph, telephone, or radio to places where there is no phototelegraph. Furthermore, a skilled drawer can draw from the verbal portrait a real one, fairly close to the image of the wanted person. Such reproductions in certain cases were printed in newspapers or put up at posters, and helped the search. And so we would like to have a computer make a verbal portrait so that to avoid errors from which even the best expert cannot be guaranteed."

"But this all again comes down to pattern recognition," the mathematicians went on explaining patiently. "And a computer in order to be able to identify or describe in digital terms a smell, a photograph, a handwriting, or a fingerprint, needs a highly specific analyzer, chemical, graphic or whatever. And in this respect man is so far beyond competition. We recognize an acquaintance from a distance, by walk or bearing. And we can not only say that it is a man or a woman, but can identify a person by name. 'Pattern recognition' is the term for the problem of teaching a com-

puter to identify images by their features. And we will have to teach it to code features on its own. But so far we have not very much to boast about here. This is now one of the key problems of cybernetics."

And still the jurists won out. Several years after the discussion they got what they wanted. Cyberneticists at Leningrad produced a machine to test the validity of signatures. To begin with, the machine was shown several authentic signatures. It fixed in its memory specific features common to all the samples. This was a teaching stage. Then the computer was shown some signatures among which were faked ones. It identified them with a probability that was only up to an experienced graphologist.

Jurists got another valuable gift—an algorithm was worked out in Riga that enabled them to compare photographs taken from different angles. But criminologists want more—they are looking forward to having a computer investigator. They again attack computer scientists: why is there a computer dispatcher, a computer bibliographer, a computer chess player, etc., but there is no computer investigator?

To one such discussion they invited Berg. Feelings ran high. Berg was sitting and observing this fight; at first he was smiling, then he blushed—a sign of an explosion—and... rushed to the podium.

"It's always useful to go over from common places to specific actions. I suggest the whole caboodle to go to Professor Vishnevsky's clinic and get acquainted with his experience of diagnozing diseases using a computer. The doctors have taught the computer to diagnose a disease from a set of signs. And it is doing so fine now that it challenges their best professors. Recently they differed in opinions and the winner was... the computer. Now then, we must take a lesson or two from clinicists. After all, crime is a sort of disease—a social disease. We can enter into the computer memory histories of previous crimes. By comparing each new crime with thousands of earlier ones (and capacities of computers grow constantly, and so does their speed), the machine will help us not only to identify the culprit, but will draw a clear geographic map of delinquency. It will indicate problem areas, for hooliganism, down to a region and a house. It will be of help in crime prevention, since we will be able to concentrate our attention on anticrime propaganda in these areas."

Needless to say, that both the jurists and the mathematicians applauded Berg, and the talk turned to specific snags to be encountered in developing the computer investigator.

This all was quite recently. And now the section "Cybernetics and Law" instituted in the Council for Cybernetics has prepared already a good many surprises for present-day Sherlock Holmeses.

Undeciphered Scriabin's Code

In a small hall filled with two pianos sat a dozen of people of various ages. All of them stared at the hands of a black-haired dark-skinned youth, flying over the keys.

Prepairing for an important concert the pianist was "dress-rehearsing" his programme before his friends. One of them invited me. All night we heard only Scriabin, and a first-class rendering at that.

Nearly every music lover passes through a period of passion for Scriabin and it is like a hurricane for him, Scriabin leaves him captivated and dumb-founded. Each piece by Scriabin—an étude or a huge canvas—is a tantalizing challenge, both for pianists and musical critics, a technical, esthetical and philosophical challenge. Scriabin is not only hard to play but also hard to understand without perceiving a musical theme in connection with his Weltanschauung and philosophy. And around this so many stories have been spun that few connoisseurs can give a reasonable answer to questions of those who love Scriabin's music.

That night everything was as usual: disputes, different understandings, different interpretations.

The pianist, closely associated with the Scriabin family, and a pupil of Henrich Neigaus, a brilliant Scriabinist, after the concert told us much unknown about the life of the composer. In conclusion he pronounced a phrase that shocked me:

"Do you know that Scriabin was thinking much about mathematical interpretation of music? He had peculiar musico-mathematical thinking and before putting down a new piece in notes he wrote it using mathematical formulas."

Beginning with "Prometheus", Scriabin wrote a light track alongside the note track—for the first time in the history of music he attempted to link light and sound.

All his works are programme ones, they have specific

subject-matter, and Scriabin wrote literary comments to them, often in verse. He synthesized in his work music, poetry and light. But mathematics?

"No, those were not the formulas so familiar to mathematicians and physicists," explained the pianist, "that was a sort of digit code that was only clear to its author. Sometimes, after a work had been put down on a note-paper, some lines and some bars were left unfilled."

"Wouldn't it be much easier to leave them out completely?" noted somebody.

"This is exactly what some musicians advised him to do, because when playing a sonata or an étude, they would find no gaps or omissions. But Scriabin answered that according to his calculations there had to be some bars there, but which he did not know yet, but they would be there by all means. And really, in the final rendering they would appear."

"And do you know that code?"

"No, nobody knows it."

"Did some mathematicians crack it?"

"No. Although there are some pieces written both in note signs and in the digit code."

What a tempting prospect, to decipher Scriabin, one of the most enigmatic, complicated and contradictory of the Russian composers.

You can recognize Tchaikovsky, Beethoven, Wagner, or Rachmaninoff, even if you do not remember the name of a piece. To recognize Scriabin is all but impossible, so changeable is his style over the various periods of his creative work. But it is not only the atmosphere of a piece that matters, but also the technique, texture, and harmony of the late Scriabin differ so drastically from the earlier Scriabin that one is tempted to assume several unknown geniuses are hidden behind his name.

Even among musicians one can encounter incompatible opinions about him. Some say that the real Scriabin is the Scriabin of the early period: his concert, first three sonatas, preludes, études, mazurkas striking with their subtle liric, the romantic atmosphere of love, fiery dramaticism. You may well find in him some hints of Chopin and Arensky but no amount of borowing can blot out the amazing hand of Scriabin—his peculiar tempestuous rhythms, ornate strained intonations.

Scriabin is also considered "real" in his middle period: in the famous "Divine Poem" and other symphonic works with his own literary texts, about which one can say in Scriabin's own words "I'm going to say people that they are strong and mighty".

And then came something verging on mysticism. Bursting from his pen were some startling (not only for his creative activities but also for the entire history of music) works replete with polyphonic dissonating accords, strange keys conflicting with classic euphoneous and melodic major-minor themes.

This jump seems to have been totally unprepared. It was unaccounted for, unclear, mysterious. It precipitated jealous disputes of the contemporaries, or sarcastic comments, or simply deprecation.

We will leave alone ignoramuses, but Ivan Bunin, that refined connoisseur of Russian culture, in the words of Valentin Kataev, so spoke of Scriabin's music:

"Scriabin? ... Hmm... You want to know what is Scriabin and what is his music, "Poem of Ecstasy", for example? I can just tell you. So, they start: "One pulls one way and the other pulls the other way". But at first it is more or less as usual, as is proper for the famous Moscow Conservatory. And suddenly, quite unexpectedly, comes a squeal of a violin, just like a pig being butchered: 'I-ih-ihh!' Bunin makes an angry face and squeals all over the place".

True, Boris Pasternak was of the other opinion of Scriabin: "... voices come nearer: Scriabin. Oh, where should I run from the paces of my divinity!"

If one could believe in the words at least of geniuses! How simply could one unravel the secret of the unravellable: what is good and what is bad.

"... *War and Peace* is a boring novel, written in a clumsy style. And damsels there are all mincing and mannered. One can hardly imagine a novel more undesirable and schematic." The author of these lines is Turgenev.

And the opinions of Leo Tolstoy about the music of List, Berlioz, Richard Strauss: cacophony, no melody, sounds offensive for the ear!

"This is devoid of rhythm, harmony, sense, this... this is just madness, blind alley. And the later Scriabin isn't even worth speaking about," raged musicians, "experts", Scriabin's contemporaries.

"Why not worth?" others were seething, "You say not worth speaking about, but the real Scriabin only started in the later period! Everything written by him till the 50th opus is just a hint, an expectation, an exercise for the lofty talent. Yes, yes, and his famous heroic period and "Prometheus", and his "Poem of Ecstasy", are all just precursors of the grandiose things to be heard in his last sonatas and what he had to unfold in the main thing of his life, in the unfinished "Mystery". And this is actually Scriabin, the real Scriabin. He was on the verge of a grandiose discovery, revelation, upheaval in music."

These heated disputes continue into our times.

Perhaps, Scriabin was in music what Einstein was in physics? Einstein, who created his theory of light quanta and relativity so early, that even now scientists argue about his theories. What was to be expected of his contemporaries? Recommending in 1912 the already well-known Einstein to the Prussian Academy of Sciences, Max Planck and other major physicists wrote that he should not be reproached (!) for his hypothesis of light quanta!

One should not pursue the external analogy between Einstein and Scriabin too far, but something of the sort also happened with Scriabin when he in "Prometheus" had written alongside his note track a light one. At the time there was much gabble about that strange innovation and the famous composer was advised not to toy with such triffling things. But it turned out that the theory relating light and sound was not just a caprice, a whimsical work of imagination. As it has been proved now, it has a real scientific foundation behind it and is deeply rooted in the most mysterious and valuable treasures of nature.

Einstein once more springs to mind—even being beyond some physicists, his theory exerted sort of a magic action on laymen. Einstein was a subject of universal worship. His address appeared in guides. He became a legend in his lifetime. A girl from British Columbia wrote to him: "I write to you to find out whether you exist in reality or not?"

Scriabin's name, too, became a legend during his life. And not only thanks to some surprising and outlandish assets of his character and biography. Enigmatic and not understood by his contemporaries, he died tragically slightly over forty, having failed to make the main thing of his life. He may well be on the threshold of a revolution.

So, a blind alley or an insight?

Who can unravel the mystery of Scriabin?

Or maybe this is a job for cyberneticists? Why shouldn't they try to decipher the mathematic code of the composer? After all, they have cracked the writing of Maya, a tribe that has long ago been exterminated. And their results completely coincided with those achieved by other techniques.

They might as well shed some light on the mysteries of one of the most remarkable musicians. And it may well be that the deciphering of Scriabin's technique will pave the way for some other interpretations of the world of sound and harmony. Could it be that Scriabin heralded a new music, inherent in our vehement and rushing age. An age that has brought into science the rebellious and audacious spirit of negation of old and establishment of new truths, an age of "crazy" ideas, which appeared to be the driving force of progress.

Well, scientists seem to have been the first to understand and sense the stormy temperament of our century and now they no longer dismiss "delirious" ideas: they are looking for them eagerly, expecting from them answers to the most puzzling, the most mysterious enigmas of nature.

Paradoxically, the boards of some journals do not accept papers that do not contain that novelty, that mesmerizing "crazyness". Of course, not engine efficiencies better than 100 per cent, not perpetual motion, and other rubbish. But the hitherto-unaccounted and fascinating powers of the human brain, and thinking habits that make it possible for the reason to free itself from routine things, from rhythmic, consistent logic of the previous knowledge and to plunge into such niches of human thinking of which the humankind has been unaware or has only a vague idea.

In this way the theory of relativity was produced, and in this way the ideas of Bohr, de Broglie, Heisenberg, Schrödinger stormed into the edifice of classical physics. They only refused to believe the apparent, they started off with a paradox and unearthed for mankind the secrets of life of the tiniest building blocks of matter, from which earth and people, stars and flowers are made up. It is exactly such a crazy idea that physicists are thirsty for today, especially in elementary-particle physics. Science calls for crazy ideas.

Insight or fallacy? How often this question comes in the

wake of breakthroughs, surrounds those names which in the final analysis come down in history as geniuses.

And what about music, the world of harmony, without which it is impossible to imagine our life? Couldn't it be that a moment of great changes will come some time in the future? Perhaps Scriabin was a pioneer, a bearer of the crazy idea of transformation of music.

What a favourable opportunity for a happy marriage of cybernetics and music, for a union of musicians and mathematicians, for a union of physicists and lyricists.

This joint venture might be a new stage in the study of the most subtle sphere of human activity—the sphere of creative work, and we will bridge the gap between one form of creative work and the other, will understand the enigma of the musical, literary, or mathematical turn of mind.

Berg, who knew and loved music, was fascinated with these opportunities. He understood that interpenetrations of disciplines, views and approaches might yield unexpected psychological effects and discoveries. In this respect, cybernetics has breath-taking prospects.

And perhaps they will bring the humanity to the future when "art becomes more scientific, and science more artistic; having parted in the foothills they will meet some time on the summit".

Why Do We Need Emotions?

Berg was one of those who clearly understood the value of the new science for the future and who even in its early days predicted its revolutionizing role in the development of civilization. Berg once said: "The superiority of man as a species and his chances to continue in this world reside in his ability to forsee situations in the surrounding world, that is, in prediction."

Man has inhereted his ability to predict from animals, in the primitive form of conditioned reflexes. We can say in full confidence that the Pavlovian dogs could forsee the appearance of food after a habitual bell. But man, in the process of his evolution, has passed from a chain of reflexes to conscious behaviour, to thinking, to conception of cause-effect relations, to true prediction.

These arguments can be continued into the fields of

engineering sciences, social life, and then prediction power comes to the fore. And as with any power, men are differently endowed with it.

When the early insights of cyberneticists opened up for the mankind a new path to cognizance of man—the path blazed through automata—men of science especially endowed with the ability to predict appeared to be of huge value. They were naturally concerned with thousands of questions. Would it be possible to get an insight into spiritual processes through automata? Is thinking and creative activity an exceptional privilege of the human brain or some devices can be produced that would possess the same powers? Where is one to start and what principle is one to use for "creative" automata? Do machines have conscience and psychology?

The traditional views had to be revised. And this was difficult, unheralded, unprepared. The books on the physiology of man and on life sciences in general published in the middle of 1950s seem to have ignored automatic control. Automatic control was thought to belong to engineering sciences only. When the question appeared on the agenda of joint discussions among engineers and psychologists, many just panicked.

But those able to predict said: "We should dare".

From the very beginning Berg strongly believed that automata would give us some clue to the workings of the intellect. He could believe in facts and quantitative evidence, and this evidence showed that there was no other way to understanding of mental activity. A radio scientist, he could easily get instructive hints: a radiotechnical device contains hundreds of switches, resistors, capacitors, inductors, valves or semiconductor elements; computers, from 10 to 100 thousand; the human nervous system includes about 15 billion neurons. A full analysis of a radio device with 200 elements takes about 5 hours. How long would it take for a naturalist to analyze the nervous network with 15 billion elements? A simple arithmetic problem: for 200 elements 5 hours, for 15 billion elements X hours

$$X = \frac{5 \times 1.5 \times 10^{10}}{200} = 3.75 \times 10^{8} \text{ hours} = 40\,000 \text{ years}$$

This result is quite convincing for a representative of exact sciences. The only conclusion is as follows: at the

present level of science it is impossible to understand mental processes directly. We should use automata as models. What is more, physiologists complain that neurons are too small to handle conveniently. Even under a microscope they are difficult to study. They are so tangled that cannot be investigated separately. On top of that, one should connect some measuring devices to them to get some information about their work.

Berg had not only to believe in the might of cybernetics himself, not only to get other people to believe in it, but he had always to be on the alert in order not to let castles be built in the air.

The prospects and possibilities of cybernetics were assessed by different workers so differently that at times the resultant dissensions became dangerous. In the same 1962 some angry voices were vocal negating cybernetical biology, and Academicians Kolmogorov and Kolman (joined by many other men of science) started the discussion the heart of which was given by Kolman in the paper "Can machines have psychics?"

"Yes, they can, such is, actually, the content of utterances of Academician A. N. Kolmogorov," writes Kolman, "When Kolmogorov says that using cybernetic methods 'it is possible to analyze life in its totality, including the human conscience in its total complexity', we fully associate ourselves with him. When Kolmogorov considers that it is possible 'along the path of the cybernetic approach to the analysis of vital phenomena to create a real life, which would continue and develop on its own', with this again we can and must agree only in the sense that this approach will be of enormous help for biochemistry that tries using its specific techniques to achieve artificial synthesis of protein bodies, and living matter. But if Kolmogorov believes that such 'artificial living things capable of reproducing and evolving progressively, and in their higher forms possess ing emotions, will and thinking', will be automata, he is under great delusion."

Kolmogorov is a most interesting personality, his works are always impressive and deep; and he has his own opinion of the potentialities of cybernetic machines.

He thought that it was possible to make automata that not only reproduce all the properties of man but even surpass him. Such automata could even possess the properties

of living things unknown to us, which may live on other planets, and that these automata will help us to get an insight into their psychics. Such a viewpoint, according to Berg, was dangerous at the time.

Reviews of the collected works *Problems of Cybernetics* showed that attacks on cybernetics had not ceased, they had just taken another form. Earlier authors were against cybernetics in general, later ones were against it under the disguise of its champions who were only concerned for its future.

Laplace once came up with an original project of communicating with the Martians: to construct on vast Siberian planes the drawing of Pythagoras' theorem so that the Martians would know that the Earth is inhabited by intelligent things. And at the time it seemed that the main difficulties would emerge in producing a sufficiently large symbolic figure. Only later came snags of principal nature. What if the inhabitants of other planets, say Jupiter, do not know solid bodies and live in a liquid medium, what then? They will have a geometry of their own, different from ours, and so the Pythagorean theorem will not impress them. Is it possible to imitate their mentality and emotions using terrestrial models?

In the earliest days of cybernetics discussions about superrobots were flaring up. Criticized and revised were such concepts as thinking, conscience, and emotions. By comparing the human organism and the automaton, scientists easily found analogies in such concepts as "memory", "idea", but had difficulties in seeking something like feelings in machines—machines obviously were doing fine without them.

"Why are emotions given to man?" asked some. "They are unquestionably a luxury, excesses of nature. Love, joy, sorrow, that complicate moral and psychological life of a man and are so burdensome for the nervous system, are not necessary at all, as shows the experience of using automata. It is a fairly straightforward exercise to make a machine capable of wagging a tail, but there may be no machine that could experience the feeling of joy, could be friendly, enterprising, beautiful, could fall in love. And nevertheless a machine, doing without feelings and emotions, may function in the spiritual sphere."

"Nonsense", answered others, "feelings are one of the ways of responding to the surrounding world, a means of restoring the mental balance of man, his health, and elements of automatic control."

"And conscience?"

"Conscience is a mirror of the external world and mental state of the organism. This is like the beam of a searchlight, which glides over the surface of the landscape and the inner world of a man. Each subjective experience corresponds to a certain state of the organism and, above all, to the state of the nervous system."

"But these are just words, how do we know the proportions in which the world is reflected in that mirror? The ties of man with the external world are not known, not described in terms of physical concepts."

Unknown, reasoned Berg, but this is the subject of cybernetics, and so they would be known. This was just the beginning. When the first railway was constructed, not many travelled by it, it was dreaded like fire.

He was interested not in abstract speculations but in hard facts. And the relation of emotions to the physical state of the organism is obvious, emotions influence the state of blood circulation and vessels. It is known that when man is gripped with fear, his muscles get limp. In 1925-27 the physiologist R. Wagner established that the response of the muscular system to loads can be described by physico-mathematical methods. Some preparations as is widely known may cause sensations: drugs, alcohol, some medicines.

Berg argued: "If one is to follow the theses of cybernetics, then to each physical state of the organism there corresponds some subjective mental state, and vice versa. What is 'corresponds'? And how is one to pursue this parallel in studying on automata the mental and thinking reactions of man? Or maybe this is as hopeless as using automata to get an insight into the psychics of the Martians?"

So Many Men So Many Minds

Berg was snowed under with such questions and doubts, when he was reading Soviet and foreign books and papers, disputing with his colleagues, meditating. He was thinking

hard about a problem that he had never encountered as a seaman or radio engineer, he was thinking about one of the most dramatic and enigmatic human problems, the mystery of thinking. "It is quite obvious that thinking cannot be separated from the concepts of time and space... It came into being and was developing in time... As man was evolving on Earth, so were the forms, information content, and effectiveness of his thinking. The prehistoric man thought otherwise than the modern man. The future man will think differently from today's... Thinking is a mental process, and all the mental processes are information processes, whose material agents are physico-chemical (and hence energetic) processes in nervous networks of the human organism, that is, physiological processes... An obvious chain of patterns and relationships is a knot of physiology, physics, chemistry, mathematics, and psychology of the living organism. Hence a striking thought: psychology is a science concerned with the information contents of physiological processes in the nervous networks of the human organism. Thinking is only inherent in man, it came about as a consequence of his needs. Some time in the past man started thinking, he is thinking now and will think in the future in accordance with his needs. Once his major concern was adaptation to the environment, survival.

"As an organized society emerged, its aim became the establishment of living conditions, the meeting of personal and social needs, that is, thinking was always purposeful, there is no thinking in general, without point. Man would not have started thinking, had he lived in an information vacuum. A single man in a social, information vacuum can neither live nor think. He dies. Man thinks because he lives not only in a gravitational and other physical fields, but also in an information field, whose material carrier is the medium."

As a logical consequence of these meditations Berg developed his own definition of thinking:

"I believe that thinking can be defined as a purposeful mental informational process that emerged as a result of satisfying intellectual, physical and social needs of man. It follows from this definition that cybernetics was bound to emerge. The modern problem is thinking and cybernetics. Cybernetics came into being as a result of continuously developing and growing needs of man, it is directed to the

improvement of the efficiency of human labour, to a wiser organization of life and activity of human society. As the forms of life and labour get more complex, so do the processes of control of technical systems, and man needs (again a need!) technical means of improving the efficiency of information processes of control. Electronic computers, these amplifiers of mental processes, are necessary and unavoidable. But they are not rivals of man and will never be such. They have no needs, they are dead. And dead matter has no needs, personal, family, social, hereditary, acquired, that is, when speaking about thinking powers of machines we mean formal assets of thiking, not its creative, heuristic aspects. We only speak about imitation, about a model, about an analogue, about a replica. And this analogue or replica may be arbitrarily close to the original, but it can have no needs of the original."

So the scientist approached a new problem from a general position of natural and technical sciences, from a position of cybernetics. He discussed his stand with psychologists, teachers, biologists: argued, surrendered, won; something brushed aside, something added. With some ideas he parted easily, others were more difficult to part with. (The most difficult for a man is to part with delusions that have struck deep roots in his mentality.) He welcomed all that stemmed from a fresh way of looking at things, deprecated routine and obstinacy. He was confident that thinking and conscience were the subject-matter of cybernetic studies, that is, of a joint venture of physicists, mathematicians, biologists, chemists, radio experts, and the more extensive and representative would this cooperation be, the better. Only a cyberneticist can treat conscience as an objective process, which can be expressed by formulas, equations, numbers or models. And again Berg was at a premium, since he could understand the process of arrival of inputs from the surrounding world to the conscience in the language of radio. Radio sciences learned to determine the quantitative aspect of the process, to deal with information flows coming in through various channels (why not nervous networks?). Biologists found that the amount of information that the nervous system is able to supply to the brain is about 1 bit in 1/16 second (a bit is a unit of information). And this portion of information stays on the surface of the conscience for about 10 seconds. Man thus

accepts 16 bits a second, and at the same time his "on-line" memory retains 160 bits of information.

When an assumption is quantifiable, this strongly suggests to a scientist that a phenomenon is physical in nature. Hence each response corresponds to a state of the organism that can be described in physical terms. But a physical effect may switch on and off conscience, stuff it with information artificially (hallucination in alcoholic and drug intoxication, horror dreams after a lavish late supper, muddle thinking in fatigue, hypnopaedia, stimulation of some forms of behaviour by electrodes introduced into the brain).

A knowledge of the mechanism of conscience, the path of information inputs, the quantitative side of a process, will make it possible to simulate the process, to create a model of the phenomenon known as conscience. Thus, the assumption that an automaton may be supplied with conscience, or rather its imitation, was not ungrounded for Berg. He was confident that a computer can be endowed with an artificial conscience.

It would, of course, be interesting to prove this speculation, to create this "conscience", but experiments required would be forbiddingly expensive.

In this way common sense, using the parlance of cybernetics, helps to effect automatic control of the search, to create around the problem an atmosphere of objective analysis.

From the very beginning Berg had been stressing the initial premise of cybernetics, namely the similarity of information transfer processes in animate and inanimate nature.

Admittedly, the paths along which information makes its way into the "flesh and blood" of man are more complex than communications channels in technology. These paths may be the hereditary mechanisms through which information is passed over to children via genes and the varied sound, visual, etc., information from the external world, and the information of intercourse between people. Each sort of information has not been delineated distinctly so far. But this is not important. Important is another thing. When the first quantitative patterns have been found in relationship of conscience and the external world, conscience and the inner world of man, it is no longer necessary to call in some "spirit" that is allegedly controlling in some

mysterious way the mental life of man, his inclinations, esthetic categories and other manifestations of intellect. Although we still refer to intellectual life as spiritual life, it has long ago lost its right for that name. Spiritual processes begin to be assessed not only in qualitative but also in quantitative way, and powers of "spirit" are now completely out of the question.

Even a dose of artistic information providing a certain esthetic pleasure can be worked out for each individuum separately. Should supernatural power endow a man with some foreign conscience, substitute some other conscience for his own, the man would surely derive pleasure from another music, other paintings, other books.

The German physicist G. Franck maintained that sound information may only be a source of pleasure, if its flow does not surpass 16 bits a second. If the flow is larger, the man-receiver becomes dumb to it, the flow becomes too burdensome for him. If the flow is lower, the receiver is underloaded, with conscience filling in the gaps with extraneous thoughts and observations. We say: the music is boring.

Quantitative evidence of this sort is of enormous value for science. It provides for investigators a large body of information on the basis of which important conclusions are made, and gaps are filled in the consistent sequence of scientific assumptions and hypotheses.

Berg viewed Franck's experiment as confirming the need for studies on the rational theory of esthetic information. In the future a rigorous theory might be developed to account for artistic activity, which might give some clue as to why something that one man perceives as beautiful, the other perceives as ugly. It may well be that science will be able to provide explanation for the proverb "So many men so many minds".

These questions could not but captivate a man with such a creative imagination as Berg's. Comprehending deeply all the aspects of cybernetics from philosophical, political, scientific, and esthetical points of view, he was carefully preparing a programme of studies on cybernetics in the Soviet Union.

"We should consider producing a theory of fantasy", said Berg, "no, not in order to tickle our nerves, but in order to predict seriously future forms of life. Application of

cybernetic techniques is going to influence our life more than atomic technology, more than space flights. At present we can hardly picture specific forms of future life, since we use previous habitual categories, our imagination cannot yet escape from the vicious circle of old views. This requires scientific fantasy, a science of prediction.

"What is more, we now seek knowledge without giving too much thought to its results. And the results may turn out to be rather curious and important. Knowledge of the fact that some aspects of the higher form of mental activity are peculiar not only to kings of nature, and that mental processes, if only formal ones, are not our exclusive privilege, but are clearly acceptable to machines, may turn out to be for the self-conscience of man as revolutionizing as the discovery of the 'shocking' fact of the insignificance of the Earth on the scale of the Universe. At one time this seemed to be a staggering revelation: the Earth, the home of Man, is not the centre of the Universe. But, on the other hand, what a flood of discoveries and ideas brought this fact in its wake! What vistas opened up before the human intellect! What freedom of thinking it gained!"

Berg had hard time, because he was swimming against the current. Against the inertia associated with the fact that after the Renaissance learning started quickly to specialize, to branch, to deepen. All of sciences once descended from their single progenitor, philosophy, and ever since kept running asunder at a quickening pace. Cybernetics is a way of uniting the sciences anew. It is called upon to bind the various sciences with one another, to enrich one with another, to tangle, to collide paradoxes, questions, challenges. Cybernetics seems to be the only way possible to rebuild the temple of science. But in our age of narrow specialization such an approach was viewed by some as quite unnatural, as an attempt to make a U-turn. Therefore, since his first days at the Council for Cybernetics Berg was painstakingly seeking contacts with people endowed with imagination. Among them were men of science and letters. In them he sees his effective support. Admittedly, journalists sometimes draw a long bow, he said, but perhaps silence or belittling the potentialities of cybernetics is more harmful. People should clearly realize that they are living on the verge of a new period of civilization, on the verge

of an era of automata, which at present are at about the level of the invention of the wheel.

"Many people, even progressive ones," said Berg, "do not show much concern for the possible consequences of the wide development of cybernetics. They may even snobbishly boast that they understand nothing of technology, that 'low' science, it is somehow below them. We, cyberneticists, do not conceal our doubts, errors, excesses. Smooth sailing is only possible along a channel marked out by others. But we are looking for new paths. And this involves experimentation, search, success and failure. In science this is called trial and error. Only thus real science is made. The more we dispute now, the more we check one another, specify our ideas, the easier would our life be later. Recall that in that respect machines cannot replace people. They can take over the torch from man only when a new science or a new discovery has grown out of its initial phase and shaped into an ordered system of knowledge, worked out its language, algorithms understandable to machines. In that stage of development the idea no longer excites a researcher, and automata should come on the scene, which are more adroit in 'juggling' with algorithms and which can continue the development of the 'vein' discovered by man. And the pioneer-man will again take care of the most difficult thing—the burden of new discoveries and searches, he again will be out blazing new trails. Nature placed into one cubic decimeter of the human scull so many possibilities, that they have no technical equivalent so far.

After man had dropped the idea that his Earth was the centre of the Universe, it took him 400 years to understand clearly the shocking fact that some mental processes may occur not only in his brain. Now knowledge is accumulated at a higher pace than earlier. A hundred years ago one generation might give a fairly accurate prediction of what expected the next generation, and we now only raise our hands. Therefore, we should be vigilant and waste no time on weakening scepticism."

Chapter Four

The Happiest Day

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Are Yogis Right!

Snowballing... For some reason this image comes to mind when I picture the scientific career of Berg from radio— a tiny initial ball— to cybernetics, a huge ball.

Whence did Berg's energies come, enough to keep the ball rolling? What was the secret of his successful activities? How did he manage to have so many people involved, people of different specialities, to help them to understand one another? How did he himself manage to flame up with so many desires?

Thousands of letters kept coming in to Berg, laden with ideas. From the old acquaintance perpetual motion to a "corrected" theory of relativity. Hundreds of inventors applied for help, he was always concerned with somebody's difficulty, another unrecognized discovery. Berg never held those enthusiasts in derision, and if they suggested some nonsense, he would say directly—nonsense; if he found a mistake, he would help to remedy it; if there was some promise, he would say: this is important, we'll fight together.

Berg's co-workers knew dozens of cases when he helped people to push through valuable ideas.

A radio engineer from Riga invented an apparatus for crushing stones in ureters. The device could save thousands of people from the hard operation, since it did the job using shock waves produced by a series of electric discharges. Americans offered a prize of 10 thousand dollars for the idea of such an apparatus. Nobody could make it, though. But Leo Rose fell ill and tortured by those stones hit upon the idea. But it took him several years of fighting with red tape and conservatism to swing the production of his apparatus. Rose was in despair. A friend of his once advised Rose to go to Moscow, to Berg.

The rest of the story is a piece of a fairy-tale: now this apparatus is widely used in clinics.

In the same vein, Berg was visited by E. Fialko, an engineer from Tomsk. In the early 1940s he, then a student at the Aviation Institute in Moscow, had designed a new form of radar and had even defended his graduate project on this topic. Berg, having learned about it, had come to sit in at the procedure—at the time he was attaching so much importance to each new work. And now Fialko, already an assistant professor at Tomsk University, worked out an ingenious technique of detecting meteors and came to Berg for support. Their friendship lasted for years. Such examples could be multiplied no end.

One could come to Berg not only to his office but also to his place, and tell him about a new idea. He would never brush it aside.

Berg was approached with all conceivable questions. Once Berg discussed a work by some physicist on the influence of electric and magnetic fields of the Earth on the human organism. The question has fascinated people since time immemorial, and it is open still. It interested even Yogis, who devoted much space to it in their treatise on health. They hold that man has harmed himself greatly when he has put on clothes and footware, thus disturbing the natural contact with the electromagnetic field of the Earth.

Berg liked the young man and promised him his help. I was surprised listening to them: why should it interest Berg? Why did he attend to this? Why didn't he save his time? My questions seem to have gotten under his skin and in a couple of days I got the following letter from him:

"As regards assistance to the work on the problems of the influence of electrostatic and magnetic fields on man, the situation is as follows. I've been interested in the question since 1944, when it was found out that X-rays coming from radar screens were detrimental for the health of personnel. This question is now attracting a lot of attention, partly in connection with space flights (an astronaut lives in an intensive radiation field), and also because in sanatoria and hospitals it has been established that sharp changes in magnetic fields during thunderstorms exert their harmful influence on the human organism. During those spells there are more infarctions, and feats of stenocardia. This is an interesting field of contact of physics and bio-

logy, and I've been watching the progress in this field for many years. I will continue this work by all means.

"I do not regret that in my time I helped Rose, Fialko and dozens of other useful people, and I plan to continue this 'useless' work to my last.

"You ask why I consider my assistance and the use of my influence and authority in certain cases more important than work on some (!) monograph. First, because I have never written 'some' monographs; second, because for three years now I have been writing diligently and devotedly a monograph, or rather a polygraph, or a book entitled *Teaching and Cybernetics.*"

A Compliment of the 20th Century

The word "push through" became all the rage these days, with a host of meanings attached to it. Some swing their personal interests, others public interests, thus forming two social poles. The former are spoken about reproachfully, the latter with gratitude: "Here's a good fellow, a good swinger!" The same intonation may well have been used referring to Raphael—he is a good painter, about Tolstoy —he is a good writer. And now one may hear: this business must be entrusted to N., he will swing it. "Pushing fellow"—this complement born by the 20th century is a far better commendation in our turbulent times than all the complements of the last century.

Berg had been "pushing through" all his life. This became his need. His "pushing through" activities seamed to have gotten in a rut. But this was only an outward show. This kind of activity, unlike many others, was nonstandard, so that the earlier experience was of no use in many cases. Each time everything had to be started anew—the nature of the "strength of material" changed. Accordingly, the method should be changed. In one case, the snag was the red-tape, in another, scepticism, in yet another, the seeming clarity.

The latter case emerged when Berg was fighting for reliability, that eternal characteristic of any product, which has been perceived only recently. In our days reliability is synonymous with quality, but it is far from being so.

In one of his talks Berg said:

"Reliability and high quality of production are the most

important of all the questions of technical progress. Should it not be solved, it would be absolutely out of the question to expect any improvements in the control of national economy and complex dynamic processes we encounter in industry, transport, communications, and warfare.

"Cybernetics, cybernetic machines, this all may appear to be just an empty whim, a bit of hot air, if 'thinking' machines would be unable to think. Reliability must be considered a criterion of no less importance than efficiency of any machines and products, from exotic ones to household appliances. Just imagine a lorry driver stuck on an Arctic road because his car failed before its rated life. Goods will not be shipped in time to start a long chain of down-times and losses. The car will have to be towed to the nearest repair shop, and this, considering the distances typical for that region, will cost a pretty penny. Matters may be somehow mended if people are not hurt. And what losses we incur through unreliability of household appliances—radios, vacuum cleaners, electric floor polishers and what not, without which the life of the modern man is unthinkable any more. Expenditures on running a network of repair shops are sometimes comparable with the costs of the factory, but in what terms is one to measure the moral damage, wasted time and effort?

"Of course, reliability should not be provided at the expense of quality. We do not need ponderous slow machines, 2-kilogram electric razors and other technical freaks. Ideally, a device should work during its rated life and its components should wear evenly. Fail-proof operation and cost-effectiveness are two main criteria.

"And despite the vital importance of production of first-class devices, reliability and quality are our sore points. The situation should be changed drastically, these problems should be solved once and for all," said Berg.

There should be none of that careless attitude to reliability. In fact, things are not so easy. It can be shown that the problem only seems to be elementary (well, if you want reliable products we will churn them out!). First, a machine is manufactured by man, and not one man, but a team. This is a source of errors.

A hundred years ago, for a master-craftsman to make, say, a good clock meant to machine and polish each component with special care, to assemble the components care-

fully, even reassemble them if the clock did not work perfectly. That was all. The process of manufacture was easily subjected to control.

When a large batch of sophisticated computers are produced, and a thousand people are involved in the production, one cannot be absolutely sure that in the array including tens of thousands of components one would be able to pinpoint a failure after assembly. Even the most experienced engineer would waste much time and effort. And even if the production is fully automatized, and the computer is manufactured by another machine or system of machines, this system, even if impeccably designed, goes wrong with time. And at some stage of production man will have to interfere. It is inevitable—he makes calculations, drawings, assembly. He is a repairman, trouble-shooter, and debugger. And man normally fails somewhere. Either because of fatigue, unintentionally, or because of carelessness, laxity. According to statistics 50 per cent of failures in modern production occur because of man (a new facet of the man—machine problem).

Fifty per cent! Those of these 50 per cent that are due to a worker feeling unwell are more or less justified. But the rest? How about those defects that are caused by laxity and carelessness?

Berg thought the propaganda of conscientious devotion to duty as his important occupation. He visited enterprises and contributed to improvements in reliability and quality.

This struggle became for several years his most active occupation. One of the measures was the establishment of the Scientific Council for Reliability. He organized a section for reliability at the Council for Cybernetics and started a campaign for an absolutely new approach to the estimation of the quality of products. Quality became the main criterion.

Once, an obscure Saratov plant initiated a new style of work. They introduced a novelty, very simple but exceedingly fruitful. There was nothing revolutionary about it, and it did not seem unusual. To begin with, it was strictly forbidden to change anything in the established production processes, which were a product of a scientifically justified approach, and such a law was introduced: a workman himself was responsible for a defect. Before submitting his products for quality control, he himself checked everything

and eliminated defects, if any, and only when confident that no component would fail he submitted his job. High quality became at a premium.

A worker checked each product, whereas quality controller carried out sample check, with some products passing as "good" and others rejected as "bad". The management insisted that not a single faulty detail would get to further operations and assembly. If even the slightest deviation from the norm was found in a batch, all the batch was returned to the producer for rechecking. If a worker submitted a batch without a single defect he got additional bonus. Just a single defect and he lost the bonus.

The factory became unique. It produced faultless machines because all the components were faultless. Other Saratov enterprises followed suit, then enterprizes in Ryazan and more than 5 000 enterprises in other towns.

And everything started with a trifling thing—not the slightest deviation from the drawings.

By the way, reliability and durability are no synonyms. Not always it pays to seek excessive durability in a machine, since with the modern speed of progress machine tools, gear and all become dated faster than wear out physically. And so it is not profitable to make them for centuries. This requires a sense of measure, account of economical and other factors.

It is time to pass from the problem of consciousness to a problem that accompanies it. Or rather to the second reason why the issue of reliability is not that simple, as it might seem at first sight. If you even suppose for a moment that all the workers of a factory producing computers are all angels and nobody would allow any junk, even if the management strictly followed the production processes, they would still be unable to manufacture reliable products, not until they master the science of reliability. And this is a real, serious science, which appeared recently and which many engineers oversimplify or ignore. Berg showed to doubters the latest books on reliability; rich in formulas, graphs, diagrams, they were written on the basis of the latest achievements of mathematics.

Berg said: "This is a most complicated science, and strange as it is, only few are interested in it. Many people do not consider it real science at all, and we thus throw out millions to dust bin."

He gave much thought to his lectures. It was important for him to be understood not only by scientists, but also by production engineers and workers. Promotion of cybernetics required training of scientists, now it was necessary to rely on those who embody the ideas of designers with their hands, that is, on workers and engineers. And those, listening to Berg, realized all of a sudden that they were invited to participate in a most interesting thing. Dry and formidable science transformed before their very eyes into a fascinating, nearly detective exploration.

But the secret here lied in the charm of Berg himself, his talents of speaker. I remember one lecture on this topic. He furnished such examples and paradoxes that the audience roared with laughter perhaps more often than while enjoying a comedy. So he read a decree of Peter I:

"I rule that the owner of the Tula gun factory Kornila Beloglaz be beaten with a knout and sent to exile to a monastery, because he, scoundrel, dared to sell to the czar's army unfit flint guns and fusils.

"To beat headman olderman Flor Fux with a knout and to send him to exile to Azov, so that he would not stamp bad guns.

"I order the Gun Office to move from St. Petersburg to Tula and observe day and night the fitness of guns. Let clerks and sub-clerks see how olderman stamps guns, should any doubt emerge, they should themselves check guns by sight and by fire. Fire two guns a month till they go wrong.

"Should some confusion occur in the army, especially in battle, because of lack of vigilance of the clerks and sub-clerks, those must be beaten with a knout relentlessly at the nude bottom:

"Owner—25 knouts and fine a *chervonets* per gun, senior olderman—to beat with a knout till he faints, senior clerk—to send to *Unteroffiziers.* Clerk—to make a scribler, sub-clerk—to deprive of Sunday's glass of vodka for one year.

"I order the new owner of the gun factory Demidov to build for the clerks and sub-clerks houses, and such that they were not worse than the owner's. Should they be worse, let Demidov not take offence. I will order to take his life. Peter."

"Terse and clear! If we could use such a decree," concluded Berg, "Just to correct the language a bit, but to leave the meaning as it is. Mankind has softened somewhat during the last centuries. In ancient Babylon there was such a law: if an architect erected an unreliable building, he was executed, if a building collapsed and there were casualties, all the members of his family were executed."

Well, our admiral was not that blood-thirsty. This was just a witticism and a good illustration. He loved picturesque examples and enjoyed close contact with the audience. He was thus recruiting his following, his speech was just like the song of Sirens.

Berg was always easy to understand, the flow of his thought was clear and well-organized, his tongue was sharp. His demeanour was so hearty, so meltingly simple and so concerned, that it was impossible not to be entailed by his preoccupation. He was possessed by his business, and that impressed people.

After him another speaker was making his presentation, he was speaking about very important things, but how? His report was so boring, schematic, that the import of what he wanted to get across to the audience left no impression on it.

A minute ago the respectable people in the hall were laughing like children and were expressing mischievously their complete acceptance:

"That's it. Well said!"

But now they yawned stealthily and glanced boringly at their watches.

Berg was not afraid of calling a spade a spade, and using a wide palette of expressions from fairly innocent "Where am I, at a meeting or a madhouse?", "He is an utter idiot. He must be dismissed.") to sharper ones. And he was more than confident that this helped the cause. Helped, because one should not be feeble and limp when a situation requires strain and drive, where at stake is the prestige of the country, its safety.

The issue of reliability had occupied Berg's mind since he got on the submarine first-hand experience of what a failure of hardware might mean. He remembered wrong-indicating measuring devices and compasses, all his sleepless nights spent over deviation tables.

One of Berg's cronies, now a major scientist, having learned about my intention to write a book about Berg, said:

"Only see to it that Berg does not come out an arm-chair scholar. That would be a sorry mistake. And have in mind that he had a unique feature—he had never feared anybody."

One trait seems to be linked to another. Had Berg sat quietly in his office, writing textbooks and monographs, everything would have been nice and convenient. For him and some others: no disputes, no conflicts, no hustle and bustle. But the new, it is common knowledge, is born under the roar of the collapsing old. The "innocent" stubbornness in providing reliability, as perhaps is not generally known, is the introduction of new factories, new technologies, retraining of personnel, more severe responsibilities, additional troubles, new expenditures, and lower wages. Even if major scientists fail to see the point in it, what could be expected of chair-polishers whose planning went down the drain due to the fuss kicked up by Berg. Enterprises failed to maintain their target figures, workers lost their bonuses, and so on and so forth. And it took really much faith to fight, fight and fight ignoring the ranks of the opponents and fearing nobody, to push through, to prove and to hammer—this is necessary, necessary, necessary!

And then... sleepless nights. Drugs. After all, more than three scores and a half behind. His colleagues were at first scared out of their wits when Berg would produce a small packet and, without interrupting a meeting, would suck a small tablet of validol.

"It's all right," he was surprised at their advice to go and take some rest, "I consume sometimes about a dozen of them a day."

And in bitter frost, even over the small distance from his home to the Council for Cybernetics he had to stop several times to take nitroglycerin—he felt pain in his heart.

But in some mysterious way he made even his heart obey his desires and strained rhythm of his life.

Once in early spring, when snow was still lying on the ground in icy granules, not melting under direct sun rays, the Bergs and their friends went to the country. They fail-

ed to reach their destination in cars and got stuck in the snow. They went on foot. Berg and his friend led the way. They paused after a short walk, Berg was gasping for breath. That was the first outing after several months spent in hospital. Berg was short-winded, his face was sallow. He put on some weight, but that did not make him look healthier. No, he was still not quite fit.

"How is your heart, Aksel Ivanovich? What do doctors say?"

He glanced back furtively:

"Heart? Well, satisfactory. Doctors say it'll last two or three years. Frankly, working lousy. Unreliable."

In this way they sauntered on, now briskly chattering, and now stopping for breath. When they came to the house it turned out that the drive was waist-deep in snow. When the women appeared on the scene they saw that the host was contriving a sort of a bridge. And Berg... Where was Berg? And Berg, bored by the waiting got over the fence and, having seen that the entrance to the house was hopelessly blocked, fetched a ladder, got through a window and was calling out from the house:

"Come, come, now I'll haul you all in here!"

And while everybody was entering the house in that unusual way, his wife was staring at him in amazement: where had gone tiredness in his eyes, sallowness and edema.

He was brisk, full of energy, cheeks turned red, eyes became younger.

It may well be that in that ability to get enthralled lied the secret of his long active life, his filled to the brim working day. His working day still lasted from 5 in the morning to late in the evening. It was only rarely that a week passed without public lectures. How then did he manage to lecture for two hours after a full-blooded working day? And he was not just droning something muttering monotonically, sipping sweet tea. No, each his word was an appeal, conviction, anger, pain, hope, and always struggle. With never a note in his hand.

"I decree that Messrs Senators held speech in the Office not from writing, but only in words, so that the stupidity of each was seen better" Berg admired that ukase of Peter I.

Apart from his own lectures, Berg looked through lots of reports, papers, dissertations, and books of his colleagues.

He was writing articles and books, editing several journals, a multiauthor publication *Science and Mankind* devoted to the major achievements of science and issued in many languages. Papers kept coming in from all over the world. And Berg found time to look over each. Not once he was considering giving this up, but could not.

"It is so interesting," he said as if apologizing, "I'm thus well aware of all the breakthroughs in the world science and learn about this first-hand, communicating with many scientists in many countries. I need it badly for my main work. Therefore, I just cannot part with it".

He was one of the two editors of the encyclopaedia *Automatization of Production and Production Electronics.* He edited the collection *Cybernetics, Thinking, Life* and another one, *Cybernetics in the Service of Communism.* These multiauthor publications are real cybernetic encyclopaedias, which found wide acceptance throughout the world. He wrote *Cybernetics and Reliability, Cybernetics—a Science of Optimal Control.* Together with Kolman he edited the book *On the Possible and Impossible in Cybernetics.* And above all he wrote an unimaginable number of prefaces, epilogues, articles in newspapers and magazines!

When the tired heart made itself felt and confined Berg to bed, his friends urged him to quit working and come to live in the country, to write memoirs. After all, he may allow himself to have a bit of quiet in his declining years.

Out of the question! In his vocabulary there were no words "quiet" and "retirement".

Entre Nous

Berg had accomplished in his life what he even could not dream of, and had given science so much that it would be enough for several workers. Cybernetics is making its strides and there is no stopping of it. And in his personal life he was having at last mellowness, happiness and warmth, this all was so much like his days at Orenburg, when the peace and harmony, friendship and understanding of the Berg family were forming the character and inclinations of young Aksel and were shaping his ideal of a family. Something of the sort was now in the home of Bergs, some moments were bringing to mind the best moments of life, what he was seeking during the entire 75 years of his life.

Berg and I were looking over the manuscript of this book. His daughter Rita was also making her contribution to the discussion. She was scuttling about the study with her brand-new textbooks—she was a schoolgirl—from time to time pushing down from the desk a folder or a treatise. Her face was purple and it was not surprising: she had a ski parka on. I asked:

"Rita, why that parka?"

"I'm a Snow-Maiden."

Yellow hair, blue eyes, a Solveig, a Snow-Maiden.

Once she was a timid, melancholic child, even languid. After she had been placed at kindergarten, she changed noticeably: became more vivid, bright, loud (used to a larger audience). Frankly, I had not thought that Academicians sent their children to kindergarten. But Berg said:

"She must be in the company of children, in a collective."

I am looking at Rita and shift my eyes to a miniature on Berg's desk. This picture in an old fitting shows a girl. The girl is amazingly beautiful and a bit incongruous on the desk of a scientist.

"This was painted by Nora in her younger days," said Berg.

Couldn't it be that she dreamed of such a child? Or rather—they dreamed... How much had been gone through ever since—the war, evacuation, how many abodes had he changed since. In his home there were few things from older days, one of them was that miniature...

Berg adored his daughter. When his friends congratulated him on his daughter's birthday—Rita was one year old—he answered them with the following letter:

"I cordially thank you, my dear friends, for your exceptional attentions and for your congratulations. I'll send today your telegram over to Marfino to gladden Raisa Pavlovna.

"It will remain a mystery for me how could you remember the date 14 July 1961, *the happiest day of my life...*"

"The happiest"—these words he underlined.

He spent much time with Rita, taught her to draw, taught her simple English words while playing with her, went out with her for a stroll, and in summer they went rowing in a boat.

"Yesterday morning was a passable weather, and I was

out with Rita for more than four hours: at first we sailed in a motorboat from the Park of Culture up the Moscow River, then we were strolling for three hours along the embankment, in the Lenin Hills and in the Park, got a bit tired, took warm baths, took a nap and were feeling gloriously after a long while. "This he wrote when he was "lying in bed" after another heart attack!

His attitude to children was touching. Once when they were staying at Malakhovka in summer, I visited them. It was a fine morning, or maybe any morning in the country will seem glorious after the oppressive heat of Moscow. We were sitting in rockers behind the cottage. Silence.

"You shouldn't think that you've got into a paradise," grinned Berg.

My eye-brows rose.

"Just wait, a kindergarten will come along."

"What of that?"

"You'll see. Each morning the same story. A young maiden, the teacher, will lie down to bake in the sun. The children will play a bit, run about for a while, and will hang on our fence. She does not care for them. And they are bored. Then they'll go on: 'Uncle, Uncle, come to play with us! Uncle, we are thirsty', and so on."

"And you?"

"Well, do what I'm asked for."

"And the maiden?"

"And the maiden reprimands me: why have I given them water, and so forth. But how can I not give them water?"

And in half an hour everything was performed in strict accordance with the scenario.

Berg had a "thing" for schoolchildren. On mission, in a sanatorium, in his country cottage, he had a way of visiting schools, contacting teachers, chatting with pupils, telling them about the advances of electronics, cybernetics and other sciences. With keen curiosity he tried to perceive the habit of mind of the new generation, their predilections and needs. Some of those contacts were fleeting, and at times an encounter developed into a friendship.

So he had formed a friendship with one Moscow school situated not far from his house—he became its permanent curator and regular lecturer.

Also regular became Berg's contacts with a school at Leningrad, the Petrischule of Berg's younger days, where he

unsuccessfully started his first school year. The pupils of the school, in which studied Musorgsky and several other celebrities, organized a museum of "their" famous people and sent a letter to Berg asking him to help them to make a stand about him. Berg asked them not to make the stand, but promised to come over and hold with them several talks about modern science, calling, selection of a path in life—and on his first visit kept his promise. Ever since the children were corresponding with Berg, were keeping him posted about their affairs, asking for advice, inviting him to come again.

An outcome of some school visits was telephone calls to the Ministry of Education or the Academy of Pedagogical Sciences—Berg was insisting on supplies of equipment for physical and chemical school laboratories, informed about shortages of textbooks, and so on.

He invariably showed interest in the state of musical education at schools. He remembered a pleasure he took in playing violin, and considered that the longing for music should be encouraged in children, because music in his opinion straightened out character, instilled patience and industry, and, of course, heightened the culture of man. Years had not quenched Berg's passion for music. Although he had long stopped playing—in 1921 he lost a phalanx of his finger—music continued to stir him. At whatever places he would come on his scientific missions (and he travelled widely) he would find time to come to a concert. His likes and dislikes in music were in conspicuous contradiction with his likes and dislikes in science. Whereas he was a hunter for the new and progressive in science, he was old-fashioned in arts. He got consolation and intense pleasure from the music of Tchaikovsky, Beethoven, Schubert, Chopin, and he was horrified by pop-music. Some motives in the Western cinema, such as alienation and loneliness upset him. He did not accept symbolism and allegory. About the Italian cinema director Antonioni he said:

"It comes out that even near ones know about one another less than about stars and planets. It is somehow farfetched. People must be sincere, and considerate to each other, to their business."

He just could not imagine that it was necessary to play the hypocrite, to deceive, and each time when he came across this (and not that rarely), he was shocked. Indecency

amazed him a lot. Belief in honesty had been with him since his boyhood. And it should be said that it did him sometimes little good. He just could not admit, could not suppose treachery in people. To win his trust was a simple matter. That was a result of some rare marriage of childhood and decency. And how often he regretted his shortsightedness.

Berg in his office and Berg at home were two different men. The former was driving, sharp, relentless. The second, kind and easy-going. But who could "isolate", to use the chemical term, the domestic Berg in pure form? Who could observe him when he was far from business, from science, from worries?

... Sunday. Morning, no different from others. Only the war and diseases changed the routine.

And that morning, too, when his family was sleeping, and the telephone was silent, Berg managed (three hours is quite a long time, if used rationally) to finish a manuscript of his booklet on reliability and scribble notes of a report about automatic collection and collation of scientific information. Another half an hour the house was coming alive and he devoted this time to putting his papers and books in order. All letters and manuscripts he arranged in folders with enviable neatness, so that they would be always at hand, although the folders were multiplying menacingly.

He ruthlessly sorted out books into three groups. Only a few found their way to his bookshelves at home or in the Council. The book flow was drowning. Most of them after a quick glance were passed on to the library. Let them serve people. Books are too valuable a capital to lie idle on shelves. They, like funds, are useful when in circulation. He kept only those books that could be looked up repeatedly and only those which were difficult to find in a library. Nine o'clock, a Sunday unfolds sluggishly, like in most Moscow families. The Bergs just had their breakfast. Raisa was washing up. Rita, in a red-blue sailor suit stuck around her and whimpered, she was a bit unwell and mother had left her at home. A bell rang. Another journalist. He had hardly time to ask the traditional question: "What's new in cybernetics?", when another bell came. A colleague walked in.

"Just to initial some papers."

Berg did not belong to those who sign papers without reading them. He trusted his co-workers, but the sense of responsibility was inherent in him. He reconsidered each phrase, sometimes introduced corrections and returned a paper for revision: from time to time he made notes in his working papers and this meant that by signing he did not forget about the document and that the work would be continued.

At last the stack of papers disappeared. Before the colleague had gone, he noted in passing:

"You know, Aksel Ivanovich, the report prepared for the conference on pedagogics failed in your absence. The speaker refused to make the presentation."

"How come?"

"He said that nothing would come out of it, without you."

"He cannot without me? Well, just imagine, a professor, a professional teacher cannot make a report on teaching?" Berg was pacing furiously to and fro, "I order to have the report been delivered in my absence. I am going to Minsk, then to Leningrad, no more procrastination."

A series of calls, from which one may infer that a staff member of the Council for Cybernetics was invited by the Academy of Pedagogical Sciences to present a paper at an All-Union Conference on Pedagogics. There were 22 contributors to the report. Several times the report had been heard at the Presidium of the Council and rejected. And so another hearing was necessary.

"I can't endure it any longer!" Berg literally shouted into the receiver. "For one thing, I'm leaving, for the other, my deputies can do it instead of me. On the 17th the report must be approved! On the 25th, when I come back? I'll now come to you and smash all the windows. On the 25th I'll be in Leningrad, I'm absent, you hear me—absent! Why that laxity? Why does nobody want to work?"

Calls, calls...

From the next room came a howl, Rita stormed in, rushed on father's lap and sobbed. With one hand Berg holded the telephone, with the other stroke Rita.

The wife complained:

"It's just impossible. We have not a minute of quiet. Even on weekends helter-skelter: people coming and going, telephone calling. The girl is unwell, she cannot sleep. And

for him it's impossible too. Just as if he doesn't need some rest. How well he writes about management. But it's all for the others. He is working like hell. High time to introduce some limits, to sleep at least seven hours a day, to take a nap after dinner. Again he has not been in the country for a month."

"Rayusha," Berg tried to justify, "my word, next year I give everything up."

"Tell that to the marines. He does not go to the sanatorium, doctors gave him up as a bad job, the whole day like in fever."

"My word, we'll make the decision, fix the programmed teaching, and that's all... retirement."

The paperman took up his ball-pen:

"What is programmed teaching?"

Berg is astounded:

"You don't know? You don't know what programmed teaching is? Well, I never! All the world and his wife are discussing it, and you don't know?"

And added:

"To-morrow, at nine, come to the Council..."

... One More

Life

The memory of Lactantius is sacred to me, although
he disputed the sphericity of the Earth,
and similarly the memory of Saint Augustine,
who recognized the sphericity of the Earth,
but disputed the existence of the antipodes.
I also respect the modern official opinion,
which admits that the Earth is fairly small
in comparison with the Universe, but disputes its motion.
But the most sacred thing for me is truth.

from **J. Kepler**

Chapter One

How to Become an Einstein?

Testing Rotten Apples

I opened the door a little way and, trying not to attract attention, sat quietly on a vacant seat. In a small room at a T-shaped table were sitting about 20 people. But I had no time to count those present, to have a good look at their faces. The first words I heard made me startle.

"There is no science of psychology, no science of pedagogics," was orating a grey-haired lean man with gay eyes.

What century had I got in? Psychology and pedagogics are ancient sciences... May I have entered a wrong door? No, I distinctly remembered a notice on the door saying

"Scientific Council for Cybernetics at the Presidium of the Academy of Sciences of the USSR". That had been my destination.

At the head of the table was sitting Academician Aksel Ivanovich Berg, Chairman of the Council. Among the audience were many familiar faces, and the speaker, who made me doubt my sanity, was familiar too: the prominent Soviet psychologist Professor Nikolai Zhinkin. But what was he speaking about?

"Yes, psychology as a scientific discipline is nonexistent. This is just an obscure arty-crafty field, far from exact sciences with their mathematical precise formulations and quantitative criteria. Uncertainty of positions is a bane not only of psychology. Pedagogics, medicine, biology will get nowhere without a union with mathematics. Medics and biologists have already made conclusions and their branches have entered a phase of prosperity. With us the picture is the oppostie. Psychology as science declines. We get several professional psychologists a year! This is a drop in the ocean. What can you expect from them?"

Everybody got excited: it was beyond belief. Professor Lomov quickly sketched the division of psychology into branches: psychology of vision, psychology of speech and memory, psychophysics... about 15 in all. He showed the list to those present and commented:

"No college produces such specialists. This is bleak reality. Alas, it's characteristic not only of the Soviet psychology. The gap between us and the West is not large, they too have little achievements."

"And still in America the Psychological Society has 22 thousand members, and in the USSR only one thousand," noted somebody.

"It's only natural, they issue more books on psychology! Look," Lomov showed a beautifully made book on mathematical psychology in English, "this is quite a modern level."

Berg immediately calls Mir Publishers to make arrangements about translation of the new book. There, it seems, the importance of the order was grasped not at once, because Berg raised his voice:

"No, of course, one should not be carried away by everything in foreign science, but foreign experience should be taken into account. It's a must! Without mathematical psychology, psychology at the up-to-the-minute level we

cannot change the educational system. And only that country will be at the top where education is arranged better. Remember what Lenin said: cadre, cadre decide everything. Why am I calling?"

Here Berg capped the receiver with his hand and said to the audience:

"I'm asked what has psychology to do with cybernetics," and again into the telephone. "These days the science of teaching breaks into the sphere of psychology, physiology, mathematics, pedagogics. A modern institution of learning has thousands of students and instructors. This is a major 'enterprise' calling for an efficient system of control of the most complicated processes, those of thinking. Without a knowledge of the laws of thinking it is now impossible to improve educational systems. And the laws governing the activity of the human brain come under the umbrella of cybernetics. And so our Council should provide for the development of psychology.

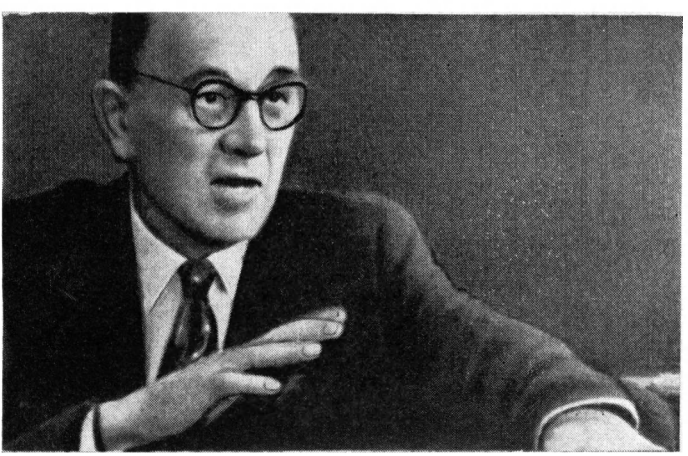
"Not only psychology but pedagogics as well stagnate for centuries. They have not changed a bit. We now teach as our forefathers did. But if our fathers and grandfathers could use the same school textbooks and the education they were given in their younger days "served them faithfully" for life, we and even more so our children must study continuously, till our last day. And to study in other ways, in another tempo. The trouble is that now a student is crammed with factual evidence only, but he is not taught thinking.

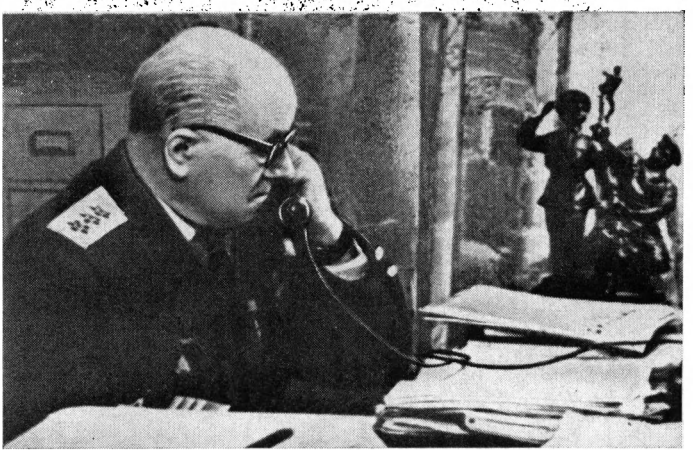
"The present way of teaching looks very much like the primitive and cruel way of teaching swimming: by throwing a child into water, let him stand up for himself. Incidentally, there is a measure of common sense in this technique: even if a man is left on his own, he will still accumulate some experience and his brain will learn thinking itself. But such a way is terribly wasteful.

"We should teach man to think more economically," Berg continued to persuade somebody at the other end, "to control the process of his thinking more effectively. To guide, programme the work of his brain so that discoveries would come to it easier and insights would become a lot of not only the happy few. This is the task of the science of control, the task of cybernetics, using which psychology and pedagogics will get a second wind. We should teach man

The dedication of
a monument to A. Popov
in Leningrad

In the heat of activity





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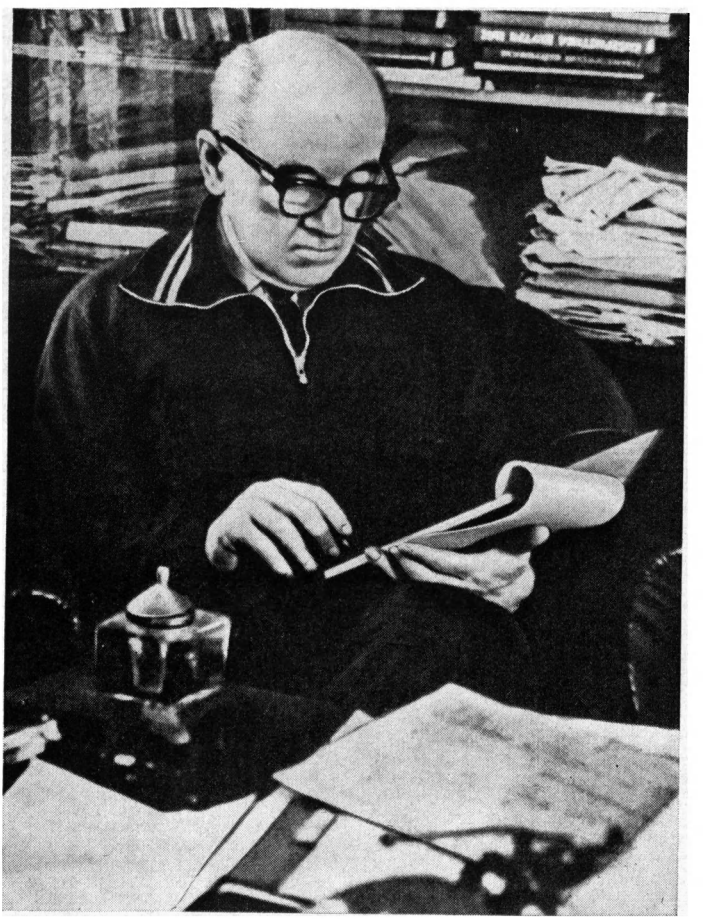

Father and daughter
going skiing (1964)

A team of radio experts
(from left to right): V. Lbov,
A. Kugushev, V. Volodina
(the widow of a well-known
radio engineer),
A. Berg, and A. Zhivotovsky

to think. We should seriously take up the problem of programmed instruction."

So at a meeting of the psychology section of the Council for Cybernetics I heard once more the term "programmed instruction", about which now write newspapers and magazines all over the world, and which holds promise as a way out of the impasse to which mankind got through the ever increasing flood of information.

"I've heard about programmed instruction at about the same time as you", Berg told me after the meeting, "and, frankly speaking, was captivated by this problem. What an audacious intention—to make the brain function more effectively. What a beautiful, fascinating dream..."

"But how to control the uncontrollable, with the process of thinking being so far a thing in itself. What a sage can say what is going on in a man's head? A man has studied, understood, created. But how studied, how understood and how created? Up until the present the work of the brain has been a mystery. Not for nothing many scholars refer to the human mentality as a "black box". As a matter of fact, we know deplorably little about ourselves. Why do some write verses, and others prose? In what unimaginable way do images and associations blossom in our mind? What do the minutes of insight, and inspiration mean? Why may the brain sometimes be exhausted in search of an answer and now it comes easily, out of the blue?

"I was so interested in these questions that I decided to get to the bottom, whatever the cost. Should years be required, I'm ready to spend all my remaining years. Should the problem require retraining, I'm ready. I started off with reading reminiscences, memoirs of people of creative occupations, painters, writers, scientists, those who possessed a high potential of creativity, that is, production of ideas. I wanted to grasp the secret of their careers, to understand how a spark is striken that sets their imagination on fire. How many different 'ignition systems' I've unearthed! Einstein, Bohr, Schiller, Helmholtz, Chaplin... What generators of insights! Well, let's turn to Charley Chaplin. He believed that creativity is associated with moods. An artist may be stimulated by a beautiful piece of music, a seascape, a glorious spring day, etc. etc. etc. But inspirations are rare occurrences. Sometimes for days on end the artist just

Cybernetic machines
— the teacher's assistants

Berg in a college
in Minsk inspects programmed
instruction in action

cannot produce a triffling thing—no mood, no inspiration, no blessing.

"Here is, for example, the revelation of a major mathematician, Academician Dorodnitsyn:

"I'm no poet and no composer, therefore I wouldn't dare to judge how inspiration comes to them. What is more congenial to me is the essence of inspiration in scientific work. A scientist is interested in some problem, he thinks much about it, constantly accumulating pertinent information, seeks ways of solving it. The accumulation process may last long—many months, maybe years. But at last the evidence accumulated reaches a required completeness, and then the way leading to its solution becomes clear. Naturally, the scientist is full of joy, even ecstasy, he forgets about all extraneous things, totally plunges into work and during several days accomplishes what earlier took years, seemingly fruitless years. We say about such a state of the scientist—inspiration came to him.

"In these two outstanding people—an artist and a scientist—the nature of inspiration is different, and the words about it are different as well, and incentives are different," Berg continues his narrative about his original exploration, "To Schiller, I have read, inspiration would come together with the smell of rotten apples, and so during his work he always put them in the drawer of his desk. The physicist Helmholtz normally went for a walk into the woods to think over final solutions. Hemingway worked standing. And Agatha Cristie, they say, writes lying in a bath, and especially breath-taking crimes occur to her when a vase with apples stands nearby, although the fresh ones. Obviously, one can carry out a curious study of how people make their brain become an obedient tool. But what is taking place in the mind we do not know still."

I listened to Berg, and dozens of questions emerged in my mind. Really, who can say why Beethoven has written his Moonlight, why Tyutchev's poems are so stirring, why people cry over the novels of Pirandello or the music of Chopin. Why it was Maxwell who understood that the world is permeated with electromagnetic energy, but it took the genius of Einstein to produce the theory of relativity. Why Sechenov and Pavlov could uncover some of the secrets of human mentality. How Townes, Basov and Prokhorov hit upon the idea of masers and lasers and why no math-

ematician during half a century could tackle the "unhappy" thirteenth Hilbert's problem, and it was solved by V. Arnold, at the time a student of Moscow University.

Having found answers to these questions we would be able to teach children in a more problem-oriented way. To create Einsteins, and Mendeleevs, Shakespeares and Pushkins.

How does the brain cover the distance from ignorance to knowledge, from dumbness to insight, how does it utilize the accumulated experience?

Berg only shrugged his shoulders:

"One thing is clear: a discovery never comes as an extrapolation of what has already been known earlier. The most significant makes its appearance as some jump, often in the form of an insight, apparently unrelated to the previous developments. The brain depends on two devices, so to speak. One processes the evidence known from the previous experience, constructs logical chains, correlates, classifies, analyzes. The other makes sudden jumps, introduces something significantly new, not associated with the previous consistent patterns. This second tool is generally called intuition. It is intuition that enables one to pass from a falling apple to the law of gravitation, from apes in a cage to the formula of the benzene ring. Even Descartes came to the conclusion that discoveries are fruit of intuition. The same opinion was held by many modern psychologists. But what is intuition? Nobody, in essence, knows this so far. Nevertheless, although this sounds paradoxically, intuition may be developed. Intuition is born and develops on the basis of extensive and deep knowledge in various, sometimes quite distant domains. And these resources of the human brain are inexhaustible. Creative potential in us is inexhaustible as well. Pavlov said that the human brain harbours so many possibilities that during a lifetime we are unable to use even half of them. But can you please tell me why one man can make a discovery, and another, working side by side with him, cannot? Tell me why Einstein became Einstein?"

Berg's question would baffle anybody. I would like to meet a man who could answer it. In the final analysis, the famous physicist, by his looks, was not especially different from other people—a charming, handsome, shy. But what a mighty intellect! Will people really never learn how his

brain worked? That prodigious machine. By what laws? How his thinking formed, what were the features of his mentality? It would be ridiculous to suppose that one could control the development of the intellect without knowing the laws of thinking.

"But you could trace nearly day by day how Einstein worked, what books he read, what conclusions made."

"That's it, again—the vicious question!—what conclusions he made," took up Berg, "But why did he make exactly these conclusions, not others? They say, with good reason, that the theory of relativity might have waited another hundred years, should a man with Einstein's imagination have not come on the scene. After all, everything that a man knows, everything he has learned and perceived is a result of his imagination. And imagination is inherent not only in a poet, a musician, a painter. It is, perhaps, a scientist who needs it most of all."

David Hilbert, a famous mathematician, was once asked about one of his pupils.

"Ah, that one?" responded Hilbert, "The fellow became a poet. For mathematics his imagination is too meagre."

What is imagination? What is personality? Who could answer these questions? And an answer must be given, otherwise the development of intellect will never be a controllable process. The entire history of mankind is a struggle, contest of intellects, with its victories and defeats, dramas of ideas, torments of creative work, competition of personalities.

Shaping of individualities... Personal approach to teaching each person—that is a new focus of Berg's thoughts.

Berg started from the very beginning. He was again young, and his brain was ready for a new jump. So far Berg had undertaken no specific steps. He accumulated information, reflected.

And reflecting about individual approach to instruction, he perceived more and more that this, seemingly special, question loomed high, growing into a huge problem of spiritual development of mankind. An individual approach to upbringing will uncover in each member of society his or her faculties. This will allow every person to give everything in his power to a common cause, and this is the pledge of the progress of humanity.

Unity of Opposites

Berg was a scientist, and therefore he drew information for his speculations from the history of science. The experience of men of science for him was more convincing than that of other professions. With acute interest, from a fresh angle, he explored and compared the careers of our two contemporaries, two physicists, the French scientist Louis de Broglie and the Soviet scientist Igor Tamm. They were about the same age, their scientific views had formed at about the same time, the first third of our century. They entered physics at the most dramatic, conflict-laden period of its history, when Relativity was making its way into the minds of scientists, when wave theory was yielding its first insights into the microworld, when electronics was coming in—the three whales on which rest all the great accomplishments of the 20th century.

Scientific interests of Tamm and de Broglie were centred around the world of unseen clusters of energy, the microworld, the tilting ground for Bohr, Heisenberg, Schrödinger, and other outstanding figures.

"When I began studying physics," related Tamm, "there were only two elementary 'blocks' of the microworld, the electron and the proton. Simple, clear, perfect. But before long that idyllic picture began to crumble.

"First, the electron flouted the customary laws of the behaviour of large bodies known to physicists. It behaved in some abnormal way from the point of view of scientists who got used to trusting the order in the world. Here is a source from which an electron was emitted. Here is a slit through which it flew. But to predict where, at what place it was to be looked for beyond the slit was impossible. And if the location of the electron was known exactly, it was impossible to determine its velocity. That was nonsense, unthinkable in the world of large things.

"About the motion of planets, about the flight of a simple stone through the air one can write whole poems in formulas and equations, but about the motion of electrons one could say with confidence nearly nothing.

"And nevertheless formulas show to us that in the microworld the situation should be exactly like this; if quantum theory wants to understand something in the behaviour of electrons and other elementary particles, it should do with-

out a detailed graphic treatment of processes.

"The point was absurd from the stand of classical physics, and it made the scientists of the older generation—Lorentz, Einstein, Planck—furious. Clearness, which for centuries had been helping scientists in their travels through the tangles of the unknown was vanishing before their eyes. They were puzzled, one cannot even mentally trace the trajectory of an electron. To do it, one has to know simultaneously position of electron in space and its velocity. And theory proclaims that this is impossible. This uncertain behaviour of a particle has even been raised to the rank of a principle."

Disputes and discussions raged in the scientific community. If radiomen of the 1930s could find a common language and come to a mutual understanding, among physicists the discord was appalling. Some of them trusted total uncertainty of the behaviour of particles, others did not doubt that the path of a particle is a real motion from one point in space to another. If a particle could colour its path in space, we would see its track, they maintained.

"For me the electron is a particle that at a given time occupies a certain point in space, and if it occurs to me that the next moment the particle moves somewhere, then I must think about its trajectory. The picture that I want to construct for myself about phenomena must be absolutely distinct and clear," sorrowfully said at the Brussels congress in late 1927 the patriarch of physicists, one of the last classics, Lorentz.

His mind just could not accommodate the abstract constructions that fascinated the young.

But Bohr and his disciples did not view the uncertainty of the behaviour of particles as inadmissible or unusual. For them this was an indication of a fundamentally different essence of the microworld, an absolutely novel realm of knowledge. This stand, which the "Bohrians" consolidated later on the Brussels congress, dominates ever since.

Those were the formative years of the two physicists of the young generation, de Broglie and Tamm. They had long cudgeled their brains over the fresh theory, which might dissolve the doubts of the old one. Their paths in physics were extremely interesting, although different. Coming from the same scientific background, they then held opposite opinions. From the same premises their brains made strict-

ly opposite conclusions.

De Broglie was sure that a trajectory, as a true path of a particle, does exist.

"Who could," he said with hope, "maintain with confidence that quantum physics will not return some day, after wanderings, to the views of objectivity, whose advocate was Lorentz to his death."

But Tamm was of the other view.

"There are all grounds to believe that simultaneous accurate determination of all three coordinates of a particle is impossible in principle."

And stressed:

"A number of circumstances lead to the conclusion (shared by all or the majority, in particular by myself) that in particle physics it is necessary to deepen the uncertainty principle."

Even "necessary to deepen"!

He went on to say:

"At the present time it is not yet known in what direction particle physics will develop: each worker in this field has his favourite path. It may well be, as is often in science, that schools of thought, which now seem to be different, will merge to form a unified general picture."

"Unified"—repeated Berg and realized clearly: exactly this is a manifestation of the meaning and force of human personalities, ingenious minds. By advancing in various directions they help to create a unified picture of the world. By refuting, enriching, complementing one another, they show the world to the mankind in all its diversity and complexity.

But how is a personality shaped? The question pulsed insistently in Berg's head, demanding an answer. How do powerful intellects emerge? One could say—through schooling, modern system of education. Another would say—not through, but despite it. Is it not that the entire modern system of education is designed to cater for an average mind? It is widely believed that a gifted schoolchild or a student will find ways of occupying himself, of satisfying his curiosity. A student lagging behind the class might be helped by additional classes and by his mates. Everything is thus designed for the average student, that is, the undisputable majority. And what another approach could be offered if a teacher has to deal with 30-40 pupils?

But even the average student does not live up to the expectations, he fails to grasp all according to the curriculum. One day the average pupil was yawning at the lesson, another day he was ill, yet another one he was in a mischievous mood and was intent on making and flying paper missiles. And so some pieces of material failed to sink in and irreparable gaps formed. The brain failed to connect the material consistently and no instructor in the world would be able to explain when and what his pupil lost or gained.

Well, is it that the force of circumstances pushes us back to the old system of personal tutors?—you may well ask. No doubt, they were observing their charges over the years, knew them perfectly: their specific features, habits, weaknesses. But where can you get so many mentors, what can such a teacher, a jack-of-all-trades teach today? And where can you find an instructor versed in all the subjects with equal depth? It is impossible!

Hence a contradiction? Comprehensive development of a personality calls for an individual approach. At the same time, with the modern system of education it is impossible, both technically and in principle. Where is the way out? Where are we to get instructors with inexhaustible knowledge, unfathomable memory, ability to handle a large mass of students and at the same time each one individually, keeping constantly under control the development of the student's thought, programming its flow (hence the term "programmed instruction").

For a cyberneticist the answer is obvious—such an instructor can be only a cybernetic machine.

Dreams... Dreams...

Imagine a man taught not by an instructor but by a cybernetic machine. Clearly, no machine, even the most intelligent one, will inculcate in a student such astounding gifts of nature as intuition and imagination. But it will offer its formidable erudition at his disposal.

Even now the computer possesses an invaluable asset, one beyond human capabilities—the huge memory, and capacity is ever growing. All the information could be broken down into a series of routines, from simple ones—for schoolchildren, to most sophisticated ones—for scientists.

To begin with, the machine will offer a student a number of questions to identify his level of knowledge and concentration, it will "size up" the habit of mind of its partner. This is the initial test based on which the machine will choose a teaching programme for a given, specific pupil. And then, having analyzed his level, his inclinations, etc., it will come up with the right programme.

With time the student may ask the machine ever more complex questions, and it will promote him to ever more complex programmes. The student is gaining knowledge. The larger his quest for the new, the more generous will be the machine. It will give the student the information necessary to satisfy his curiosity and will develop his activity and initiative.

This was the case of one student. Depending on the level of perfection the cybernetic instructor can simultaneously conduct several dialogues, with many students. The larger the capacity of its memory, the larger the number of students it can take care of. It is not only memory that matters here, also important are the numerous identical input-output devices: microphones for the student to dictate his questions (or keys or any other devices capable of translating the human language into the computer language), screens on which he will read the answers (or telegraph tapes or other means). The more advanced is the teaching machine, the more independent channels of communications it has, the more students it is able to cater for simultaneously (this is possible because the human brain and the computer have different speeds).

The teaching machine may be an indispensable helper not only in the initial period, but also later on when qualification will be higher. It will also be of help for a scientist on his way to a discovery.

Modern science is complicated, the roots it has struck are so deep and so widely separated that not infrequently a researcher has no idea of the work of his colleague. And their tastes and inclinations, like with any people, are different and each is going his own way. Some seek to unravel the mystery of the microworld by studying the theory of electromagnetic field. They a priori admit that the strength of that theory lies in its rigorous mathematical logic, and its weakness lies in the difficulties of processing experimental data. Adherents of that theory pride themsel-

ves on the fact that the theory is logically the acme of perfection and is an intellectual attraction. Adherents of another method of modern physics—the theory of matrices—boast the close relation of their theory to experiment. Their results are not always impeccable mathematically, but they agree with experiment. They are more practicable: from the result of an experiment they are likely to predict the result of the next one. They enable one to construct a theory of a phenomenon, always checking it up with experiment, thus progressing by trial and error, although scientists would give much so that both trials and errors were fewer.

There are also other techniques of probing into the microworld, and success may await proponents of any one of them. But it is more likely for those who can combine the advantages and powers of all modern mathematical techniques.

How happy would a scientist be if he had a possibility to test quickly many paths and to decide on the correct one. But a human life is not long enough for too many approaches to be tried. A man may devote a lifetime to his favourite theory only to see in his declining years that it has been futile and his initial premises have been false. And how many experiments he stages, how many calculations he makes seeking a confirmation of the theory, all in vain, without noticing that most important developments, which could have revealed the truth for him, have passed by.

And here comes a machine capable of doing some work for a dozen, nay for a hundred workers. A machine that will enable a scientist to outwit life—in a short period of time to try out dozens of techniques, to analyze hundreds of trials, to collate the findings, to approach them from many angles.

It is not that old acquaintance of ours, the modern computer, a sort of amplifier of mental powers. The future cybernetic machine will provide man, as it were, with an additional brain with all the information required. Not a mechanized manual or encyclopaedia, but rather an intelligent, observant, knowledgeable companion (in fact, we all draw on the erudition of people more versed in a subject), which would follow all the moves of our thinking, would guide us in the adequate direction, would stimulate our intuition and encourage fantasy. Such a machine would be a counterpart of a whole team of people with a wide var-

iety of backgrounds, able to help us in our search for an answer, to teach us more clear reasoning, at a higher intellectual level.

The 1960s was the time when the idea of the teaching machine was in the air. Many dreamed of it, including one of the most interesting investigators, whose spectrum of talents sort of symbolizes the complex intellectual spirit of our times—Hordon Pask, a British cyberneticist, psychologist, teacher, engineer. On top of that, he is a singer and a painter (one cannot help being impressed by such a richness of talents in a man). He is an acknowledged leader of the progressive school of thought in the sphere of teaching machines. Pask is looking forward to creating an army of "educated" cybernetic mentors, capable of adapting to the level of a student and flexibly changing the teaching programme. Such a machine, just like a teacher, does not supply a ready-made discovery to the student's head, but it prepares the brain for begetting a new idea. Working in close contact with such a machine, man will advance much faster than when using manuals and books alone. And he would be able to develop his potentialities at a much earlier age than is generally the case now.

Already in their early years people show predilection for one or another human activity. Having identified this sphere, the machine will stimulate the development of this inclination. It will be easier for a man to decide on his future occupation, to understand his calling, to serve society with his abilities and knowledge.

In this respect the words of Karl Marx spring to mind. He wrote in one of his early works that if the circumstances of our life enabled us to select any profession, then we would be able to choose one that gave us more dignity, to select a profession based on ideas whose validity we did not question. We would be able to select a profession that opened up for us the widest sphere of activity in the name of humanity and to bring us nearer to the general aim in relation to which each profession was only a means of progressing to perfection.

Help in this conscientious selection may come from adaptive computers. And not at the level of primitive tests so popular now, but at the level of highly-qualified mentors able to unveil the entire depth of the personality of a student.

That was the aspect of cybernetics which in the mid-1960s attracted the attention of Berg. Apart from the universal aspects of value for any society, he saw in the instructing machine some purely Soviet facets reflecting the specifics of the Soviet system of education. He considered that individual instruction would be of especial value for Soviet students by correspondence. If a person wants to raise his qualification, he will sign up for a selected course at a Teaching Centre. Time will be appointed, and alone or in a group of people of about his calibre, he will start his play with the computer. The machine will become for him a source of the up-to-the-minute, comprehensive information.

Such an arrangement will surely be better than the current one. Another additional attraction is the absence of examinations. Why exams, if the machine controls the progress of its charge step by step in the process of instruction. The machine will not change the programme till it is full sure that the previous, easier and simpler, programme has been mastered. And although it handles thousands of students, it does not become less attentive and considerate. It is capable of conversing with all of them at once. And each will have his own channel of communication.

Another important advantage of the arrangement: the duration of tuition will not be rigidly fixed, with gifted students progressing faster and with others slower. But all will end up with good solid knowledge. This will reduce the gap between capable and less capable students, between town and country, since even those who live in remote districts will be able to get first-class education.

"No, no, a machine will cause no unemployment in teaching," Berg anticipated objections, "It will make the contribution of the teacher more creative and will only eliminate the perennial shortage of teachers. In this country we have two and a half million teachers," as usual, Berg began with statistics, "and still this is not enough. This means that about one in a hundred is an instructor, or in relation to the whole able-bodied population one out of fifty. Thus, for this reason alone it is impossible to increase markedly the number of teachers. The only path is rationalization and mechanization of instruction, raising the qualification of teachers, and providing them with electronic instructing machines. As Suvorov put it—to win not by num-

bers but by skills. With cybernetic instruction the role of teacher will change drastically, his labour will become really heuristic. In conjunction with psychologists, philosophers, and workers in other fields instructors will work out and up-date programmes for their teaching machines. The new method will demand more culture and erudition of the instructor. The teacher will be an authoritative person capable of performing the most responsible work—considering the strategy and tactics of education and paving the way for further progress of mankind.

"The teacher of the future will be not just an instructor but also a mathematician and psychiatrist. Without a grounding in mathematics he will be unable to produce a programme for teaching machines. A knowledge of psychiatry will be required if a student shows some pathology. Children sometimes develop some derangements, which are often overlooked, or they are difficult to identify because of the lack of perfect contact between the teacher and the student. The machine will diagnose this with enviable precision, and perhaps the teacher-psychiatrist will be in a position to remedy the disorder."

It seems that there have been enough speculations, and it is high time to pass from words to deeds...

Reconnaissance Before Battle

In 1964 on the suggestion of the Minister of Higher Education was established the Council for Programmed Instruction, which was to provide guidance in this field in the Soviet Union. Berg was asked to become chairman of the Council.

Berg followed the proved route—at first reconnaissance to assess the state-of-the-art throughout the country. Where and who are working on the problem? What useful or harmful has been done? Who is in need of help, who is to be reprimanded, encouraged, corrected? And reconnaissance in science means conferences, symposia and other meetings attracting the workers in the field. They exchange opinions, so that everybody could benefit from the pool of experience, good and bad.

The reconnaissance yielded much evidence, both hopeful and disturbing. Really, the idea of programmed teaching had grasped the minds of many practical instructors, it had

found its way into remote schools, polytechnics and institutes. Many teachers started improvising makeshift teaching machines, which they were putting to use and demonstrating to their colleagues. They were telling funny stories about how one managed to acquire the services of his mechanic acquaintance, another to put his hands on some badly needed components, yet another to disguise programmed instruction in his plan as something else. There were no books on the subject, no help from centre, and, strictly speaking, not clear yet... what "programmed instruction" was.

The preliminary study had shown that programmed instruction in the Soviet Union was totally in the hands of enthusiasts. Perfect, it would seem: enthusiasts had produced various models for one to choose at leasure. An enthusiast is working not for money but for satisfaction, and a historical example proved the usefulness of enthusiasm—who but enthusiasts in radio were the first to apply short waves, they were the first to construct short-wave transmitters and receivers and to obtain communication at short waves.

But...

Berg was the first to feel the dangers of that "but".

Just imagine that everybody sets out to construct his own space craft: a geologist who wants to get a glimpse of the lunar geological structure; an astronomer seeking to unveil the mysterious atmosphere of Venus; a physicist eager to bring his devices beyond the blanket of the terrestrial atmosphere so that to be able to measure cosmic rays, and many others. Should it be the case in reality, the geologist or the astronomer would have to become spacecraft theoreticians and designers, chemists and metallurgists. No amount of enthusiasm would see them through. Such a picture, however, was in programmed instruction at that time. Each enthusiastic instructor made his programmes himself, urged some engineer to help him to manufacture a teaching machine or bought a ready-made one, and had enormous pains adapting his home-spun programme to it.

Each teacher who had somehow rationalized his work through quicker checking of homework or using a tape-recorder, or some electronic contrivance thought that he had accomplished a revolution in instruction.

And of course, in the majority of cases, he was in for a

disappointment. If he was stubborn, he started again and produced some improvements. But the danger of this was that his first failure might scare others off and thus do harm to the very idea. And Berg was well aware of many a case like that, for example the failure of a device for early diagnosticating of cancer. Poor realization of the idea discouraged the customers and they no longer wanted to risk their funds with further modifications of the device. This sort of dangers might await programmed instruction at the early period of its development.

Berg was afraid of this and the results of the first surveys proved that fears were not without grounds.

By 1965 a wild assortment of instructing contrivances had already been in existence, most of them were inadequate and primitive. They were really compromising the idea. An exhibition of teaching machines held in Moscow made Berg send injunctions to suspend work on some of these machines.

But this by no means implied that all the work in this sphere had to be stopped. It was necessary to carry out an autopsy, to study the negative experience. The next step on the path traced by Berg was the analysis of mistakes.

If he had not followed that sequence of actions even at the dawn of his scientific career, he would hardly be so successfull with his radar effort. In 1936 Berg and his colleagues went to a secluded place on the sea-shore to test first models. From their point of view there were no hindrances capable of ruining the tests. Squadrons of planes took to the air and barraged nearly over the aerial of the radar, and the radar failed to notice them! What a disgrace! The only conclusion was—the idea discredited itself. Fortunately, the team decided not to return to the Institute with those devastating findings but to sort out the difficulty in situ. They did sort it out, and found the culprits. Those were sea-gulls, who also loved that secluded stretch of the sea-shore and nested there by thousands in the cliffs. Scared by the planes, they took to the air with the result that their radar shadows filled up the screen.

And so one should not jump to the conclusion that the first failures with teaching machines were testimony of the failure of the method as such. Not all the initial ideas in programmed instruction were rejected by exact Berg. He welcomed the introduction in some schools of a new tech-

nique of instruction. It was far from perfection and not yet using the adapting feature, but approached the idea of programmed teaching—it was individualized. The method was as follows: the instructor introduced fresh material, then gave a problem or an assignment and the students worked on their own. In a while they started pressing one of the three keys on their desks, "ready", "not ready", "help wanted". The instructor had a console with signal lamps, three per each student. And so on the console he got the entire picture of what was going on in the class. This was just a first step to rationalizing the work of a teacher. Of course, Berg was well aware that this was a far cry from programmed instruction, but this helped the teacher to come in contact with each student.

Instructors immediately divided into two unequal groups. Most of them worked as before waiting for the outcome of the disputes and the first results of the minority, who were fighting for programmed instruction as they understood it, without expecting any guidance. And what were the prime of the science—psychologists, teachers, and others—doing, those who should be at the head of the movement?

They were arguing. Arguing about whether or not one should make use of the international experience; whether or not anything should be done without a theory of instruction (but there was no such unified theory and it was hardly forthcoming in the nearest future), whether or not the term "programmed instruction" was correct, and if not, what should be used instead.

Each school of thought suggested its theory, its form, its understanding of programmed instruction. Many suggested textbooks, so-called programmed textbooks, where the material was presented in such a way that the student could not proceed without having grasped the previous piece.

This was disputed, defended and refuted at conferences and at Berg's office at the Council for Cybernetics, which now doubled as the headquarters of the Council for Programmed Instruction. On that battlefield small fights, major battles and skirmishes were fought out. Frankly, I would often forget the subject of a dispute, being absorbed by the stormy play of temperaments. I was just all ears and eyes.

The behaviour of Berg was puzzling. He was mostly silent—he seemed not to have formed any final opinion yet.

He understood that behind the early failures with instructive machines were not just crude constructions and primitive programmes. The causes lied deeper, in the fundamental strata of the problem.

Would it be reasonable to pose the question about a new method of education, when the laws governing this process were not clear yet? In order to teach a machine to shape the thinking of a student, we should ourselves be able to do this—but are we? Do we know an answer to the vicious question—how is the human thinking formed?

What do international authorities say about this?

Berg was digging and delving for books, papers, notes, just any hints in this field. He was reflecting much, weighing the pros and cons in each case. He started from alpha, trying to perceive the essence of pedagogics, studied the history of its development. Once I found him literally drowned in a heap of old magazines.

To my bewildered glance he answered:

"*Soviet Pedagogics* for the last forty years, since 1925. Only today did I find out what pedagogics is. Pe-da-go-gics, it appears, is a science concerned with teaching children, but only boys. Humanity has grown out of it. You cannot possibly squeeze adults into children's clothes. We should start from the very beginning. We'll have to raise the science of teaching up to a level of the 20th century".

Journals... Textbooks on psychology... Monographs... Disputes at the Council, objections, indignation, distrust...

And the main thing—Berg continued to develop his ideas.

To what conclusions would they bring him?

The Salutary Abracadabra

What do specialists say about the mechanism of human thinking?

"How does it form? Quite simply, as has been found out by Pavlov: based on sign images and analogies. New concepts are worked out based on the old ones. New knowledge is absorbed using earlier knowledge."

This theory is easy to accept. It is graphic. It was especially vividly demonstrated by a man, who was one of the first to stimulate Berg's interest in programmed instruction, Professor N. Zhinkin. He liked, answering a question about the mechanism of thinking, to patter some word long

and tricky, for example "desoxyribonucleic acid", and offer then:

"Repeat it quickly."

And observing the helplessness of the companion, he laughed:

"You see, you cannot. You need some time in order to find, consciously, or maybe subconsciously, some familiar features in a new word, and to break it down into some familiar parts. So, the first syllable suggests something like "desinfection", then "rubber". Further goes something like "nucleone", "clue", and the "acid". Here is a way to master the new word. And in this way you grasp and remember."

"And really!" laughed Berg and gave other examples in excitement, "Such a mechanism of remembering and assimilating unknown words and telephone numbers is inherent in us. I remember that I somehow could not learn the name of my new acquaintance. Exactly because it seemed very simple there was nothing to catch on. I confused each time whether he was Vasilii Vladimirovich or Vladimir Vasilievich. And suddenly it dawned upon me! My new acquaintance was 'Migulin, vice versa'! Professor Migulin was Vladimir Vasilievich. The problem was solved."

The human psychology en route to new concepts always rests on old and familiar concepts. This was no discovery for Berg. This was borne out by the very development of science. Studying electricity scientists proceeded from the properties of liquids. By visualizing water infiltrating sand one can readily pass on to electrons finding their way through the atoms of a substance, thus forming an electric current. The laws of motion of a liquid lay at the bottom of calculations of electric wires.

To illustrate the calculation of orbital motions, Kepler in 1596 manufactured a model of the solar system: five polyhedra into which are inscribed or around which are described the orbits. True, Kepler's theory actually needs no models, but a model at the time was considered as one of the greatest achievements—it helped to perceive, to "feel" the validity of a theory.

No wonder then that on the way to cognizing the world scientists above all relied on geometrical concepts. In the earlier stages those were the notions from the geometry of nondistorted space, Euclidian geometry, later on it was non-

Euclidian geometry, which suggested to Einstein an essentially simple (the simplicity of a genius) idea of identifying our world with the distorted non-Euclidian space.

The geometric theory expressed, with unexpected completeness, the physical essence of space. As one scientist put it "the general theory of relativity is an outstanding example of a theory constructed using the mathematical game of blind-man's-buff"...

It thus appears that the human imagination and thinking rely and refer to familiar images. And the entire body of classical physics is an exceedingly dramatic example of this. During the 20 centuries it has been growing on the basis of already established models, images and analogies. When a new phenomenon was discovered, it was accounted for using a model, a diagram, a drawing. Since the time of Descartes it has been thought that a real and concrete thing is only such that can be represented by figures and motions.

To sum up, the "image" theory of learning is easily believed in. And still, although people have long understood that associations are the basis of our learning, the very process of their formation is still a mystery. There are theories, hypotheses and assumptions galore. It seemed many times that the truth was just round the corner. And then physicists chanced upon holography—a peculiar way of three-dimensional imaging of objects not in the form of a visual image but in the form of a tangled pattern of light waves, and at once a hypothesis emerged: Could it be that the cells of our brain remember visual images in this way?

Electronic computers made their appearance, and now scientists are thinking that the surrounding world is coded somehow by our senses and in that way is introduced into the cells of our brain, just as into the memory cells of a computer. And in them, combined according to the principle of associative forms, our inner world, intellect, and knowledge are born. But these all are hunches, assumptions, short-lived working hypotheses. What does occur in the sphere of human thinking and how does it happen? There is perhaps no scientist who would not exclaim "A kingdom for the answer".

But Berg was quick in finding the Achilles' heel of the associative theory: it fails to explain the wandering of the human reason beyond the confines of the world of associa-

tions. It was all very well with planets and stars; they could easily be likened to a cold or fiery spheres. And what does the electron, positron, or neutrino look like? No man in the world knows that! But without picturing these "things", and having no possibility to select some analogies, or images for them, physicists have nevertheless found out very much about them: the charge, the rest mass, and other parameters. The physics of the microworld was thus born, which, unlike the physics of the macroworld, the physics of large bodies, does not rely on the everyday experience. How then could a physics without images emerge in the human brain?

Formulas Are Cleverer Than We Are

Having run across this question, Berg understood that the answer to it would clarify many other things. How has it come about then? How do psychologists account for that? An understanding of the laws governing the life of the microworld flashed through the minds of several physicists like a lightning, like a fire—like a bolt from the blue, like a bombshell. The new laws were outlandish, nearly crazy, but they provided a surprisingly accurate description of the well-known facts and predicted new ones. That mesmerized even such seasoned sages as Einstein and Lorentz, and nobody could explain the charm and magnetic force of the world that opened up before the investigators, because nobody could understand how it came about. There are some facts that can be stated but not explained.

And the facts are as follows.

Late in the 19th century Maxwell rooted out physics from the world of graphic concepts and plunged it into the world of pure abstraction. He understood that the Universe is permeated with electromagnetic waves, that light is a form of these waves, and described their properties with the help of four amazingly simple equations. Even 30 years after the production of the new theory only several physicists managed to perceive its meaning. For the others it remained double Dutch. Even in our days, when scientists have long put to use the Maxwellian mathematical tool, nobody can answer the questions what electromagnetic and radio waves are. We produce them, we use them, but cannot say what they are.

When during World War I Louis de Broglie served in the French army as a radiotelegraphist he started thinking about the nature of radio waves. Later he gave a beautiful formulation of the situation: "Present-day views cannot serve as a foundation for an understanding of these electromagnetic oscillations, which cannot be reduced to the classic and dramatic notion of oscillations of a material body. Hanging in emptiness, so to speak, they appear for uninitiated (and maybe even for physicists as well) as something rather mysterious."

It was thus asking a lot for Maxwell's contemporaries to understand his breakthrough. It was impossible for them exactly because, in defiance of age-old traditions and ideals, it did not rest on mechanical motions and forces.

The quantities that in Maxwell's treatment described electromagnetic waves could not be represented by any models. Those were the symbols of the electric and magnetic fields. In the stores of their brains scientists found no support for understanding of these abstract quantities, and hence could not feel their physical meaning. And the most curious part of the story was that the great Maxwell himself could not completely grasp what he had accomplished, and was also raking his head over a fitting model.

This goes to prove once again that it is difficult for a man even when he discovers something new, to lose touch with habitual things, with solid ground. Thought not only strives to find support in old images, but sticks to them desperately. Not without reason, having come intuitively to new concepts, scientists often try to interpret them using those ideas that have existed earlier and become staple material in textbooks or at least in scientific journals. Only after those new ideas have become habitual and striken roots in the minds of scientists, the latter are surprized: what is so complicated here, what has taken so long to be grasped?

Formulas and equations have played such a trick upon scientists many times. They would lead them into the world of enigmas and puzzles and leave them there to the mercy of fate. Such was the case with Dirac when in 1928 the wave equation he had derived suddenly tossed him up an antiparticle, and the latter opened up for him, the first man on earth, the antiworld. Dirac was not ready for that, he

had not got such a daring intention, and for a long time could not explain to his colleagues so startling a behaviour of his equation. The conspiracy of silence around Dirac's finding lasted several years, until he himself hit upon the wondrous fact that apart from matter there exists antimatter.

The same happened with Max Planck, who in 1900 wrote a formula describing the process of energy transfer from a heated body not in the form of a continuous flow, just as rivers carry their waters, but in the form of portions, quanta. The quantum of energy became sort of a scarecrow. It was unclear to Planck and other researchers. Some of them even threatened to drop physics if the outrageous theory of Planck was not rejected.

And still this "outrageous" theory, now considered an important building block in the foundation of modern physics, is widely used, and all the equations of quantum physics include h, Planck's constant, a mysterious entity, whose real meaning has been beyond scientists up till the present time.

Academician Lev Landau said: "In the process of cognizing nature man can tear himself away from his imagination, he can discover and perceive even what is beyond his imagination."

Heinrich Hertz, the discoverer of radiowaves, who confirmed the real, not mythical, life of the four Maxwell's equations said: "One cannot help feeling that mathematical formulas exist independently of us and live their own intelligent life, that they are more clever than their producers, because we derive from these formulas even more than was embedded in them from the very beginning."

The human mind has thus intruded upon the world of abstractions where not each notion could be represented graphically, where scientists are losing firm ground in the form of well-known images, analogies, and models. The physics without images has led scientists away from the world of accessible things, a world where things studied could be seen, touched or imagined.

No wonder then that even great physicists were having difficulties in accepting novel ideas.

What was to provide support for the thought of scientists in that unsteady world of abstractions? The answer of psychologists sounds nearly mystically: the thought in such

cases is backed up by intuition. Like a painter who takes from a palette one paint or another, a physicist takes one theory or another. One physicist confessed that he estimated rather intuitively than consciously whether he has taken suitable material for his purpose or not.

This seems incredible only at first sight. This feeling may emerge because the mathematical intuition, and any other intuition for that matter, that amazing property of human mentality, has not yet been explained. And although man has learned to "question" nature using the language of mathematics, scientists are as yet able to understand to the bottom neither the world of physics nor the world of mathematics, nor the involved, enigmatic relations of the two, which are especially involved in living things, all the more so in the sphere of the higher nervous activity, in the realm of thought. And no psychologist in the world would be able to explain how the imaginative and abstract thinking, physical concepts and formulas, reality and imagination get along in the human conscience.

How can one then, thought Berg, proceed from the fact that thinking relies only on familiar images and analogies, ignoring the formation of abstract constructs in the brain?

He was tantalized by painful doubts.

If it is unknown how novel ideas flash through a mind, how knowledge is formed, does it make sense to speak about the optimization of the teaching process at all? If it is unknown what occurs in the head of a student, who would undertake to make up a programme of the functioning of the brain? Naturally, the entire teaching system and all the programmes are under suspicion.

What was to be done? What was the way out of the impasse? How could the education of the younger generations be improved? Should one start as in the year dot, teaching everything that was taught to fathers and grandfathers?

Not for nothing in recent years maths lessons at schools start not with arithmetic but with algebra. To reach the advanced physics, should a student pass all the way from Aristotle? And perhaps we should recognize that by training thought on old ideas, on the Cartesian system of checking new hypotheses by figures and movements, we artificially create difficulties for our students. Perhaps teachers

must drastically revise the methods and order of teaching of physical sciences? Should students be brought to advanced physics by absorbing the ways of the old, classical physics, or maybe some other path should be followed? Despite the fact that the theory of relativity and quantum physics was "ruminated" by scientists painfully, physicists assure that in due time the basics of quantum mechanics would be taught to schoolchildren. They will be quite familiar for the man in the street.

...All these questions interwove, contradicted one another, spoiled the consistent train of thought, thus complicating the problem.

One thing was beyond doubt: these questions will only be answered with complete confidence when it becomes known what occurs in the head of a student, how his thoughts are arranged, and how it comes easy to him.

That was another impasse, and many workers were inclined to think that the time was not ripe for the teaching machine. As long as psychology was a "black box", the teaching machine would be out of business. It would be welcomed only when in the garden of the science of psychology the main fruit—the theory of thinking—would become mature.

But when will such a theory come?

Maybe in a century...

The answer of psychologists—careful and sobber—did not suit Berg at all.

To wait a hundred years. No, not for his temperament. He was painfully looking for a way out of this deadlock, he wanted to reconcile the irreconcilable: desire and infeasibility.

The strain of thought is fruitful because it often acts like a press molding shapes from a shapeless mass of material. From a chaos of unrelated ideas, assumptions, hints the pressure of thought suddenly forms a decision. Perhaps, this would not be an absolute decision, not the best way out of a situation, just a hint, a compromise. But this always serves to get things moving. Berg was groping for the possible approaches to the problem. It could be solved with the aid of a theory, but if there were no theory one should rely on experimental evidence. He was prompted by passion, difficulties inspired him. If theory was impotent, well, he would draw on experience. Tirelessly he would con-

tinue his attempts to produce an adaptive teaching machine, to look for laws of thought even if no theory of thinking had been developed yet. Machines themselves would help in producnig it—this was the final outcome of his tormenting reflections.

How? How can a machine help here?

The machine itself should be involved in the search. By accumulating years of experience of intercourse with various students, by tracing in its memory step by step the reasoning of thousands of people, it would glean for researchers unique comparative material. Well, trainers record on a cinema film the performance of best sportsmen and then step by step they analyze their movements: here a sportsman lost speed, there he made a spurt, a wrong motion, lost rhythm, and so on. Obviously, the machine would tell us much interesting about the work of thought on the way to acquiring knowledge. And psychologists would be possessors of unique graphs of the workings of the human brain, which would be of help in unravelling the mystery of reason.

Cybernetics will in time rank with two phenomenal breakthroughs of our century—relativity and quantum theory. Whereas they helped humanity to get an insight into the secrets of nature, to understand the laws governing the motions of galaxies and stellar worlds, cybernetics promises man to penetrate into the most secret stronghold of nature: the world of the human reason, mentality, thinking.

Just as Paganini was able to make his violin sound in a different way, so cyberneticists are able to teach our brain to become a tool of unbounded possibilities.

Chapter Two

The Tragedy of the Centipede

Fire!

Even though the theory of thought had not yet been worked out, Berg set before Soviet cyberneticists an intriguing and fundamental problem—to learn to produce algorithms for the instructive machine.

Boldness and readiness to take risks had always been Berg's assets. The more complex a problem the more concentrated must be the attack, he thought. It should be recognized, of course, that intellect is formed not only by images and analogies, but it also has a way of making abstract jumps. Thus, it was all the more difficult to program mental activity. Yet without a programme the development of the cybernetic teaching machine would never get off the ground, just as an ordinary machine will not roar to life without fuel. And so the programme just had to be worked out.

To produce an algorithm of mental activities means to translate man's thought process into mathematical language. If man some day masters this, it will start an upheaval beyond comparison. If a thought is written using formulas, man and machine will relate to each other as freely as people speaking the same language.

To be sure, if mathematical patterns of human reasoning were known, they would yield to programmers clear recipes of formalization of the mental process. But although research was only in its infancy, it was decided that it was impossible to wait any longer. It was necessary to find out what achievements had thus far been made in leading research centres, and who was working on algorithms similar to those needed by instructors.

Berg's attention was attracted by a young scientist working on the algorithmization of the mental process. Berg invited him to the Council to speak to the specialists about his work.

What could an outsider expect from this meeting? A monotonic narrative... A languid academic discussion...

"We would like to hear about the results obtained at your laboratory."

"Mr Berg, you've read the report I submitted to the Council, haven't you?"

"You'd better give us an oral presentation. What have your team made in the field of programmed instruction?"

The young man began circumstantially and deliberately:

"We've worked on this for a long time, about 13 years now, since 1952. We haven't transplanted this idea from America. Rather we have been led to it by circumstances at schools. When I was still a student at a pedagogical institute, and then a post-graduate student and a school teacher, I was surprised that even those pupils who knew all theorems couldn't apply them in practice. They couldn't solve problems, couldn't think. They learned to memorize things, but not to think. And no textbook contained a programme explaining how to teach thinking."

"We shouldn't be so concerned about this," noted Berg jokingly, "This is clear. But come to the point. What specifically have you accomplished in this field?"

"And so we set before ourselves the task of identifying the building blocks of the thought process. You cannot teach a man to think without knowing those blocks."

"But that's an axiom! That's self-evident! What then? What are your specific results in this field? That the process of thinking is unclear is, unfortunately, a fact. We will proceed from there. How then do you suggest we find the way out of this situation? What have you done in this respect that others haven't done? What is original in your ideas?"

"Here's an example..."

"No examples, please. What are your concrete results?"

Both men began to get angry.

"Each class of problems has its blocks..."

"Again! Look here, we cannot... we just have no right to waste time on generalities. We need a deep insight into what occurs in a man's brain. But... so many psychologists, so many minds. We do not want to set people at loggerheads. But the Council wants clearly to identify what has been done and what is to be done next. We should find

the most promising school of thought and group our forces around it, we should select a clear starting point."

Berg was upset, furious. He seemed to have experienced something like that which he felt on a warship, if after the command "Fire!" the target had remained intact.

No, he wasn't happy with the report. He received no answers to his questions. And he was pressing on, was requiring full concentration. A delay or failure made him furious. The firing at a target must be hellish, without delay, without allowances for a lack of experience. He was impatient and driving—he demanded that his co-workers be quick and precise in grasping the gist of things, must possess his stores of information, his erudition, his tension and his fantastic stamina. Alas, such a combination of qualities is rarely encountered, but he did not think about this, and therefore, in his ardent impatience to obtain results, was often intolerant and unfair.

Thus, a routine report turned into a joust.

Berg cooled down a bit when the man was followed by two charming ladies, his colleagues. Berg was a gentleman and listened to them without butting in. But from their first phrases it became clear to him that what they suggested was not programmed instruction, but just one of the possible ways of organizing the work of a teacher. He had heard much of that at conferences.

"This is all ever so interesting," commented Berg quietly, "regarding the system of teaching the Russian and English languages. But allow me to express my doubts. What you suggest requires huge texts. Is this really a solution? Notice that we now have wide education by correspondence, and in the future it is going to become the dominant system. When do you think an extramural student should read your tomes? Have you read the article in the *Communist*, fourth number for 1965? Half of all these students give up their studies. Half! And besides, we are short of ordinary textbooks. We haven't enough paper in the country. This is an objective background which must be kept in mind. Here're some figures."

Berg flipped through his invariable thick note-book, the size of a log-book, and read aloud how much paper per capita was produced in various countries, and how it was used. He had foreseen everything. He did not want to become too far removed from reality. Well and good, scientists have

come up with some effective technique of teaching foreign languages. The first idea that comes to mind is to have a go at it. And now tests are produced. This way of testing a technique is very expensive in terms of time and money. This is not a reasonable approach. But Berg made effectiveness his corner-stone. Therefore, he was heading for programmed instruction, for a revolution. He wanted no wasting money and time, no half-measures and compromises. A new idea was not an aim in itself for him, what was important was not a new idea but the results it could yield, its use, its value for the nation.

An Eruption of Information

How much controversy was caused at the Council by the works of a team of psychologists at Moscow University! How much time Berg spent sorting everything out and working out an objective estimate of this effort that was long-term, intensive, but one that also caused so much dispute among scientists.

Once Berg chanced upon a paper by a young American physicist, F. Dyson. The author of the paper pondered the formation of physical thinking—precisely the subject of Berg's thoughts at that time.

Dyson's reasoning impressed Berg a lot: The physicist, drawing on his experience as a student and teacher of quantum mechanics, maintained that the mastering of quantum mechanics normally progresses in three stages. The first stage (about six months) is learning the mathematics of quantum mechanics—it is relatively easy and painless. Next comes the time of tantalizing attempts to perceive some physical picture behind the mathematical procedures. Then, quite unexpectedly, comes the third stage when the student says "I have grasped quantum mechanics" or rather "I understand that there is nothing to understand here." The fact is that he has learned to think directly and subconsciously in the language of quantum mechanics, and no longer attempts to explain everything using prequantum concepts.

These arguments struck Berg, because at about that time it seemed to him that he had just hit upon the key to the paradox; he had met workers who, it seemed, revealed a radically new way of shaping of images and concepts in

the human brain. He had learned about the work of teachers and psychologists at Moscow University who were working on an original system of teaching techniques.

At first the work interested Berg, then perplexed him, then...

Well, this moment is so interesting in the evolution of Berg's attitude to programmed instruction, so characteristic of any turn in the course of scientific investigation, that it is worth dwelling on it a bit.

One evening, it seems it was New Year's Eve of 1965, about 20 psychologists gathered at Leningrad University, and Berg was invited to attend to discuss some issues of programmed instruction. That was one of those exclusive meetings, where esoteric things are discussed and an outsider feels ill at ease. An outsider, yes. But an insider?

When the Moscow team presented their results, not one of the professors present could remember reading anything about them. Everybody confessed total ignorance. Excerpts from the papers were read—the response was utter bewilderment. The authors started talking in layman's language—nonsense! Everybody was speaking about some "mental actions", "orientizing actions", etc., and nobody could explain their essence or purpose.

Could it be that only the Leningraders were ignorant of those works? Although when asked what the theory of mental actions means Professor Zhinkin answered "I don't know". Professor Samarin set out to explain something in a verbose and confused manner. Zakharov, a psychologist from the Council for Cybernetics, uttered something sarcastically in French.

What was the matter?

The deeper the experts got mired in the argument, the longer were their discussions, the more nervous became Berg. He was possessed by a passionate discontent, an impatient desire to arrive at last at something definite, matter-of-fact and clear, and having joined the forces of psychologists, to achieve some advance in programmed instruction. He, a man of exact sciences and action, was set on edge by that marking time, this juggling of obscure definitions, and lack of a common language.

After all, physics and mathematics have their beauty, the beauty of universality, the sine is a sine, not cosine or tangent. But psychologists managed to turn their notions

into rubber. It turned out that to think, to study, to acquire skills, to analyze—all of these words may be endowed with different meanings. Could it be that this was the reason why the Leningraders, and many of the Moscovites for that matter, failed to understand the psychologists from Moscow University? Even diligent reading of their papers and reports produced a wide variety of interpretations.

Berg decided to get to the bottom of the problem. He reasoned that it was hardly possible for serious scholars (Moscow psychologists were known as the major experts on teaching) to be so hopelessly in error. There must have been some rational core in their technique. It just could not have been a wanton piece of theorizing. And what if this was some important contribution that was simply too difficult to grasp all at once? Dyson, too, was referring to some unconscious operations. Maybe they were akin to "mental actions"?

The Moscow group did not deny that there was no theory of teaching, no theory of thinking, and that it was perhaps to take another hundred years for people to perceive the laws of human mentality. They agreed that the flow of human thought was based unquestionably on familiar images and notions. But nobody knows how they were formed; therefore, an artificial method of their production is sought. And so the groups of teachers and psychologists suggested a method consisting of a series of mental actions prepared beforehand on special cards. The cards were given to students and, if they followed all the commands on the cards, their conscience would retain the required concept.

The members of the team assured that they had proved their technique in some schools, and it turned out that it not only improved academic progress but also cut study-time in half. That sounded tempting! The length of time spent at schools and colleges is a plague of our times. Science develops at such an enormous pace that the bulk of information produced doubles every five years, a time span compatible with university years. As a result, a graduate must immediately start self-retraining to catch up with the advances in his field.

Some sort of "eruption" of information occurs. And it is not surprising. Statistics show that 90 per cent of men of science who have ever lived on earth have lived in modern times. Throughout all the previous centuries, in all the

countries, there lived only one tenth of the total population of scientists! In 1750 only 10 scientific journals were published in the world. And now we have 7000 publications in life sciences alone. The librarians in Detroit are said to rush about on roller skates. And machines that sort, copy, and describe fresh arrivals at large libraries are more complex than those in the most modern industrial enterprises.

An unheard-of Niagara of knowledge in all fields of human endeavour is literally flooding people. We can no longer keep in check the ever growing information flow. Scientists complain that a work may be repeated two or three times, because it is easier to perform it anew than to search for it in a sea of journals and books. People may not find enough time for rummaging through journals or even abstracts. Not infrequently even narrow specialists are unaware of works carried out by their colleagues not only abroad but even in a nearby centre.

Curricula of schools and universities keep swelling. They fail to incorporate the ever increasing flow of new findings. The length of study shows a trend of increasing, and it is shortened using measures resembling surgical operations. The situation is so striking that such a serious physicist as Leo Szilard has written a science fiction story about an incredibly tragic situation. His hero fell asleep and woke up in 90 years. He was, of course, shocked to find himself in the next century, but especially by the concern of people for how to put an end to... the progress of science, which was threatening to flood humanity.

But, perhaps, the greatest harm this avalanche of discoveries does is to schoolchildren, because every breakthrough must be reflected not only in books but also in the heads of the members of the young generation.

How can we shorten the length of study? This is a headache of teachers throughout the world. And now these psychologists from Moscow University maintain that they have solved this touchy problem.

A Recipe for Procuring Ideas

Although disputable, the technique put forward by the Moscow team holds promise as a way of shortening schooling terms. Isn't this alone sufficient to get interested in it?

Another attractive aspect of their work is that they think about new curricula, algorithms of mental actions, and this is of decisive importance for use in programming teaching machines.

It may well be that the method of mental actions will be a basis of the algorithm for future teaching machines. An algorithm that will reflect the new principle of formation of knowledge. And Dyson maintains that introducing the younger generation to modern ideas using special methods (why not the method of mental actions?) will not only expedite and simplify the process of assimilating knowledge, but will also bring about a qualitative change in that process. Beyond a doubt, the duration and pains of the so-called second stage of grasping, the stage of "torments", shortens with time. Each new generation of students assimilates quantum mechanics more easily than their teachers. Each new generation is less linked to the pre-quantum picture of the world, and therefore shows less resistance to the destruction of that picture, which comes before they begin to feel at home with quantum mechanical ideas. It is quite probable that later on, the second stage will disappear completely, with quantum theory being accepted by students from the very beginning as a simple and natural way of looking at things because they will be sufficiently accustomed to it.

One cannot help being captivated by such a point of view, and there is only one thing with which one may disagree with Dyson: he believes that such a jump in our knowledge about the microworld will only come in a hundred years. With our paces it is unlikely that scientists will wait so long. Dyson seems to overlook the enormous growth of science in our dynamic times, when ever more people are becoming involved in scientific enterprises. If the appearance of an Einstein early in the 20th century was a rare exception, then against the background of a larger population of theoretical physicists the emergence of a new genius is a more probable event than it was half a century ago. And we should speak not just of a genius but of geniuses, because the development of powerful intellects is high on the agenda of today's education. This is fully dependent on the system of education to be chosen by humanity in our stormy scientific age. Conditions for the maturing of physical ideas are disputed especially often because physics is

perhaps one of the most revolutionary sciences of modern times. And one of the most important ones. Production of young physicists is a delicate and complicated thing. True, all the modern sciences undergo vehement growth in one way or another, and what concerns techniques of teaching quantum mechanics is applicable to any other discipline.

Now then, perhaps the time is ripe to revolutionize these techniques using the theory of mental actions?

... I was fortunate enough to attend a conference where one of the authors of this new method, Professor Galperin, spoke, and I could thus learn first-hand the possibilities opened up by the new theory. Here is what Galperin said:

"There is nothing out of the ordinary in our method. Everything seems to be generally known, a good instructor has at all times taught this way, simply we have broken down the entire process into several neat stages, each of which follows logically from the previous one. This system of oriented actions must lead to the production of certain concepts.

"Our thesis sounds like a motto: in order to understand one must do. To do literally, with one's hands. It is of extreme importance to select correctly such an action which results in remembering and grasping. At the basis of any skill or art lies active work. This, of course, has been known since Adam was a boy. But there is activity and activity. One must find some type of active action that will make the teaching process the most efficient, that is, optimal. Teaching languages calls for certain actions, maths for others, literature for yet others. This all comes down to the art of the programmer finding a corresponding action. And then, no new action can be performed all at once, 'internally'. The basis for any mental action is an external, material (or materialized) action, which we translate into a mental one by means of some operations.

"And so you want, say, to teach a student to analyze some law, for example, Newton's law: force equals mass times acceleration. You work out a plan of the analysis. You write on a card in a certain logical sequence a list of actions to be performed by the student: to make a drawing, to indicate the directions and magnitudes of forces, to find which of the forces are responsible for the motion, which hinder it, to find the net force, and so forth.

"Thus, the student uses our card to determine step by

step the directions of the forces and the acceleration, to choose a system of units, to apply the formula and, finally, to arrive at the desired quantity, in our case the force. This plan teaches how to deduce one quantity from two others. And, having firmly grasped such a method of analysis, the student will use it in any other similar case."

"But this is all generally explained by each teacher of physics", someone in the audience said.

"Of course," laughed Galperin, "and I didn't promise you a discovery of America. This is, of course, explained by the teacher, but not written in such a consistent way. And this largely accounts for the spread in academic results. Often a B-child differs from an A-child in that he had missed something in that logical chain, and if he is returned to the missing link, he will immediately correct himself. With this plan of analysis, nothing has to be learned by heart or crammed. But working with it is not that simple. If something is constantly before the student's eyes, the student won't remember it. This card has to be taken away from the student in due time, to break him of the habit of using it, like a mother takes her baby away from her bosom. And only then will the student start working from memory. He names the point of action, the very action, and carries out this action. When this second stage of understanding has been passed, the next one begins. The student now does the operations without naming them aloud. He follows the plan silently, but we watch him. Control is necessary. Then comes the next stage, the so-called phasing out—the student no longer pronounces completely the entire plan, but only some key words: 'drawing', 'the direction of forces'. And finally, the entire process occurs in his mind automatically. Consequently, to perform some analysis, we have mapped out a number of materialized actions, have transformed them into a mental action and led the student to an ability to arrive at the required result.

"We have deliberately brought the student's brain through the procedure of stage-by-stage formation of knowledge. We have regulated the internal psychological process, strictly controlled the student's course of thought. We thus obtain the result we have preliminarily programmed. If you do not arrive at this result, the blame lies with you, it means that the plan has been worked out incorrectly. You've failed to lead the student to the result.

"If the student has correctly gone through all stages: action by visual plan, pronouncing it, silent repeating, repeating key words and, finally, automatic performance, that is, complete grasping without repeating, he is ready to use his skill for the analysis of similar problems in other spheres."

I thought: "That's something. One may agree or disagree with this, but at any rate, the method is consistent and clear. There is logic in it."

It turned out that such a plan can be made for a morphological analysis of a sentence, for the analysis of geometrical, historical, etc. material. And a piece of knowledge being studied will strike roots in the mind not through cramming a rule, a sure path to forgetting quickly, but by the transforming of a materialized action into a skill.

The major difficulty in the process, Galperin stressed repeatedly, is finding an appropriate action. For example, to teach a student the concept of perpendicularity he is given a ruler. To learn what a perpendicular is the student must recognize its signs: two straight lines making an angle of 90°. And the student is given the simplest model of the straight line, a ruler. And then he works with it. If the angle between two rulers is 90° and the lines lie in the same plane, hence they are perpendicular. Its model is a set square. The student acts literally using his hands, and for beginners this is very important, like using sticks or fingers to count. Now a teacher often makes the students learn the definition of a perpendicular by heart. And without being touched by student's hands, the perpendicular remains something obscure. Having "touched" it, the student will not frantically try to remember its features, he will know them firmly.

And using this procedure the student can be taught not only simple notions and arts, but also more serious ones. The notion of "mammal" can be explained, he can be taught sawing firewood, machining things, analyzing a sentence or a work of art. This can all be done using a special programme, a certain sequence of mental actions, as a result of which the student (if only unconsciously at first) will master a notion forever and without fail.

Correct usage of signs is central to the theory of mental actions. This was stressed by other researchers as well. Any concept is defined by signs. Having learned to analyze signs, the student will absorb the concept. So, the signs of

a perpendicular are two straight lines intersecting at a right angle; of parallelness, straight lines lying in one plane and never intersecting. The sign of the concept of "mammal" is the feeding of young with the mother's own milk. From its external appearances something is like a bird, but by its signs it is a fish, not a bird. And conversely, from the looks "something" seems to be a fish (for example, a whale) but it feeds its young with milk, and hence is a mammal, not a fish.

The psychologists explained that some concepts can be instilled from the early years. For example, infants are given some pictures, and they are told to find the birds in it.

"Children not subjected to our technique judged only from external appearance. And 'our' children, before giving an answer asked: what does it breathe with, lungs or gills? And how does it raise its young? Does it feed them with milk? They started by identifying the signs and only then answered: this is a mammal, a bird, a fish. They have already developed the practice of correlating notions with signs. It is this analysis by signs that is our aim. Earlier the major approach was learning concepts by heart. A definition of perpendicularity is suggested and is committed to memory. But it is possible to analyze by signs and come to the conclusion that this is a perpendicular, not any other thing. Then all theorems and axioms will appear as simple statements. This teaches one how to draw conclusions, not just how to use learned but dead knowledge."

Galperin supplied an example of analytic plans for various subjects. He already has algorithms for geography, Russian, chess, handicrafts. By the way, the algorithm for boring is remembered by pupils on the first run, for geography and Russian, from the fifth. Galperin provided, in particular, a card for historical analysis.

"I do not say that this particular algorithm is the best one," said Galperin, "perhaps you will come up with a better one, but this is the only algorithm so far."

He was asked:

"And can your plan be used in programmed instruction with a machine?"

"Of course, we've done everything that is necessary for this: divided the teaching process into individual stages, and now, using a typical given algorithm, a whole class of problems can be solved. But we think that the method

works even without a machine. And without a machine each student can be brought up to the highest level. We want every pupil to be an A-child. And now we have plenty of E-children. They are not dumb, they simply have gaps in the process of assimilation, and our method makes it possible to find these gaps and to fill them."

"What's the aim of your system?"

"To work out general procedures of thinking. To be able to translate some methods to new fields of knowledge. To shorten the length of schooling."

The method of Galperin and his co-workers seemed convincing and authoritative.

To Surprise, To Shock

In the evening, in a state of euphoria, I shared my impressions with Berg (he was ill and could not attend the conference).

"The landmarks Galperin suggests for the thought process discipline the brain, guide and organize the process of thinking. Thought is guided by the landmarks, like a slalom skier by the guiding flags."

Berg watched me with pity.

"But slalom is just a sport, no more," he said at last, "You see, they are suggesting a most boring procedure. A student will have to be guided by some card with a list of actions, and these actions he will actually have to learn by heart. Where is adaptation here, that is, adaptability to the student's individuality? Everything is designed for some average abstract individuum. And then, such a procedure is just a bore. Its authors proceed from the fact that a child has no feelings, no needs. Is there any excitement in this study? To look up something on a card, then to pronounce it, then to remember it. What a bore! This kills initiative, this quenches creative strivings. I remember how at the naval corps we constructed models of ships—forgetting all, about hunger, about time—so exciting it was.

"Well, why remember our childhood. Here's an example from today, from today's school. Children come to school and their first lesson is the division of labour in human society. Just imagine, what a verbal jelly is possible here. Brats, who were torn away from football and play-grounds, were starched, tidied up and transported to school, and who

got ready to be bored to death for several hours, suddenly hear the teacher's suggestion 'Children, let's bake pies'.

"One does not need to have much imagination to picture the reaction of the children.

"And now the class is divided into two. In one group each makes his or her own pie. In the other, they use a division of labour. One makes dough; another, moulds; a third, minces meat; a fourth, shapes the pies; a fifth, puts them in the oven. Everything proceeds merrily, quickly, productively. Each has mastered one operation and does not hold up the others. They have made twice as many pies as the other group and they are more delicious. Thus the kiddies have grasped the idea and the importance of labour division first-hand, from their own experience and conclusions.

"This is the sort of activity which stimulates learning. But the activity suggested by the psychologists at Moscow University? Won't the schoolchildren be bored by the dullness and monotony of their actions? Anatole France wrote that one can only learn successfully when learning is fun. It's important to interest students. If you don't develop interest and some need, then all initiative will go down the drain. I state that the living differs from the nonliving exactly by the presence of needs. In a child you should cultivate interest in work, in life, in knowledge."

... Reflecting much about the theory of mental actions, Berg came to the conclusion that the theory is a cry from programmed instruction. This was just one of the many possible teaching techniques, in some aspects convenient, in others not, but that was not the problem of the day. How many of them have there been—Dalton-plans and other teaching 'discoveries'. There have been so many tricks, and most of them have been forgotten, having yielded no positive results, nothing new for teaching.

"The problems are: the lack of teachers—one; teaching is not individualized—two; flood of information—three. And there is another burning problem for teachers: how to 'lure' youth to science, how to interest them, how to attract their attention. Not by chewing cards, that's for sure."

Professor K. Darrow, a prominent American theoretical physicist believed that the common method was to stun, to strike. But to be stunned a man must be an insider. Just imagine a physicist trying to impress an audience consisting

of laymen by saying that now instead of two elementary particles we know a dozen, that tin stops resisting an electrical current when cooled below a certain temperature, and that the latest cyclotron accelerates protons up to 500 MeV. So what, would be the reply.

Darrow, however, concluded by maintaining that in each field it is difficult to find an exciting and instructive aspect for a novice and to represent it in a form that would arouse keen interest. This is not given to everyone, this is the charisma of the lecturer.

Berg continued: "You may believe me, an old teacher, that the business with cards won't make a student's life any more interesting. And programmed instruction, and adaptive machines are good in that they stimulate the activity of the student. He will be able to work with the machine either at home or in class. Or, he may go to another town and still be connected to the machine from a distance, by telephone or radio. Before him he will have the control board of the instructive machine. He will press a button to switch on the machine and inform it (using a mike or a keyboard) what subject he would like to take up now. The machine will remember at what place they had given up last time and present a continuation. It will ask the student some review questions (they will be either written on the display or pronounced in a human voice). If the student is having difficulties in answering them, the machine will bring him back to the previous section and present this material in another way: through examples, new associations, problems. When at last the machine sees that its charge has fully grasped the topic, it will put him up to a higher level. If in the course of a lesson the machine notices that the student is absent-minded, and tired, it will terminate the classes untill another time. And so the man will work independently, without prompts, his brain will not be coerced. No prescribed actions for you, the machine will only keep an eye on the progress of its charge, supplying fuel to the furnace of inspiration and creative search. And some hold that programmed instruction will encourage passiveness. Rubbish! Not that programmed instruction is bad but what is currently posed off as programmed instruction. Programmes are meagre, machines are still primitive. Our systems are very bad, and Skinner is primitive and so is Chowder. If a student is given an easy

programme, this is likely to kill his concentration. Nothing falls into the mouth of a sleeping fox. That's the main task—to produce programmes that wouldn't intimidate with their undue difficulties and wouldn't spoil by lack of interest. This is for the average student. For a weaker one the machine will choose an easier teaching programme and will make it more difficult only when it sees that the student has mastered the previous material. But it won't keep an able one on elementary things, having evaluated his level, it will give to him a more difficult, and hence more interesting, programme. In this way the machine will stir the brain of the dumb students and encourage the able ones, and will lead them up to independent work. It will improve the intensity of mental work and will start the brain on the way to discoveries, small discoveries with children, and then major discoveries when they grow up."

And Berg again cites an example from school. A teacher shows two pictures to children.

"Yes, yes", he anticipated the question, "also, like with Galperin, everything starts with pictures. But, you just listen, how this story ends. That's the crux of the matter. The teacher shows a vessel half filled with a liquid, on the bottom of which lies a small cube. The cube exudes bubbles. The other picture shows the same vessel with the liquid at the same level, but without the cube and the bubbles. The teacher asks the children to guess what the cube and bubbles are and where they have gone."

"This is sugar!" cries one.

"This is ice!" interrupts another.

"This is sugar, because it melts in the water," explains the first one.

"No, ice, it melts too."

"Ice floats, this is sugar."

The children start thinking, arguing, they get excited, each trying to substantiate his or her supposition, to make a point.

The teacher, of course, does not remain aloof, she is always alert. With her questions and feed-back she directs the children to the correct answer.

"May a piece of ice look like a cube? Will sugar float? And maybe this is a dice?" she asks.

"No," cry the children, "a dice would not dissolve in the water."

"And maybe this is soap?"

"No, not soap, otherwise there would be a price on it."

For the children this all appeared as an entertaining game, but actually this was a lesson in scientific thinking.

But this was not the end of the discussion. The next day, when the children came to school, on the desk stood vessels with water, and all the opinions could be tested. The pupils took pieces of sugar, ice, soap, threw them into the water and observed the outcome. The ice floated. Only the sugar yielded bubbles, and everything was just like in the picture.

The teacher had several possibilities. She could just say that a lump of sugar, dissolving in water, gives off bubbles, and the children might even remember this. But she preferred to let them use their imagination, to dispute, to scratch their heads, to try and hold their grounds, to cut a long story short, to make it into a lesson of creative thinking.

Each child had reached the truth in his or her own way. For some it was a walkover, for others a poser, but each had put his mental reserves to full use, made a tiny discovery. The teacher was asking leading questions, but did not curb the flight of imagination.

"The lesson was conducted by a genuine, imaginative teacher," commented Berg, "Such a lesson could be conducted by a teaching machine, for which a programme will be worked out by a good teacher or a team of imaginative teachers with due account for the spread in the level of students. There's no qualitative difference here between a human teacher and an automatic one. A machine can be a teacher. And it can listen to the pupil (not with ears but with its mike or otherwise), and can answer him (on the display or in a human voice). The difference, if you wish, is a quantitative one. The machine's brain is a composite affair, as it were, it has been filled up with the knowledge of hundreds of teachers, scientists. They have equipped it with extensive modern information. The programme of the machine is its brain, its reason, created by human pedagogues. A quantitative departure resides in that the 'brain' of the future automatic pedagogue will be more capacious than that of the human one, and it will think billions of times faster. And so, while one student is thinking, the machine will be able to serve many others.

"Isn't it interesting to study with such a machine? This is an exciting game. The student will hardly notice how the teaching machine will lead his brain along the path of discoveries. Kids, even the smallest ones, can be taught complex things, but they need a special approach, this should be done at the level accessible to them, in a lively manner, suitable for their age. Only interest and rapture are able to develop thinking, to make the brain into an obedient tool.

"Just make studies into an adventure and you will prepare the student in the best way for a career of discoveries. If since his early years he is used to the method of small discoveries, he is more likely to make his larger discovery. Since childhood he will be in the habit of relying not on the absorbed information but on his own observations, on the information he derives himself. The teacher or the adaptive machine are just directing him, prompting him how best to understand what he has been told, how to analyze the material, how to get more information. The student learns to observe, and the teacher or the machine controls him, guides him and explains to him. And if such a teaching technique is combined with the organization of classes not by age but by aptitudes, the result will be startling.

"One thing is beyond doubt," Berg went on saying, "if a pupil sees every minute that he is making progress, that he is overcoming difficulties, his reward will be a feeling of satisfaction beyond comparison. The student makes one small discovery after another, and this not only teaches him creative thinking, not only prepares him for large discoveries, but is also a source of intense joy, inspiration, and a feeling of independence. Let a weaker student have it a harder way than a more able one. Perhaps, but... Another 'but'... Perhaps sometimes it pays to ease up a bit for some larger aim? Perhaps the teacher will have to spend another hour to explain what in another case would take a minute? But the student will not only remember, not only understand what is being explained, but this will lead him to an understanding of a whole class of previously unknown notions, usher him into a wondrous world. And it will make him speculate, dream, and will ignite in his soul a creative spark."

Who knows how long it will take programmed instruction to break through, but it is clear that even now it is working. It has moved a mountain—the habit of teaching. Instructors start thinking, at last, about what should have been a good start millennia back. In earlier times instructors were only concerned with the material to be brought home to students. When producing a new textbook they only thought about the subject studied. How to expose it, say, chronologically or consistently. And little thought was given to how the material was deposited in the head of a student. Somehow nobody got around to it. And students liked some textbooks, and hated others. They throng to some lectures and ignored others.

Authors of books and most readers simply did not consider it their task to facilitate the work of a student's brain. This only concerned some teachers. Others were just writing texts asking themselves whether they included everything, all the dates, theorems, laws? The form of presentation did not interest them very much. Now that there emerged the idea of breaking up the material and checking its grasping by feedback (between the student and the teacher or by self-control), pedagogues first thought: do I provide adequate understanding, is the subject-matter arranged adequately, does it quickly and easily get across to the mind of the student, does it evoke correct associations? For the first time in the history of teaching came the concern for an optimal teaching process. This all came about, of course, due to cybernetics, which brought to a head the issue of control of all manner of processes, including the teaching process. Instructors and psychologists started pondering over what for writers of popular science is, so to speak, alpha and omega. In addition to contents, one should give some thought to format. How is one to write about the most sophisticated issues of science, say about today's physics with its brain-twisting problems, for the reader to grasp? It won't do here to rely on the reader's background, since he may appear to be an Academician (non-physicist, of course) or a worker. And each time one should think of some interesting clear analogy to lean on, and of some illustrative example. And all the time one should place oneself into the reader's shoes, to guide him, anticipating the se-

quence of his thought, in order to direct it, to develop the thread of consistent arguments. He would not be called upon to learn by rote, and more so to "cram", but rather to develop a feeling. And here any trick may come in handy. The reader must be interested. He does not ask for "tips" and does not forgive arrogance. To say that an electron is an electron means to say nothing. And the reader, having seen the author's impotence, will put the book aside.

It is necessary that the reader should at first understand the matter at least in outline. Then the author goes over to particulars and here again he groups for accessible analogies, associations, now more subtle, more specific. And all the time the author seeks such a course that leads the reader on, arouses his curiosity, evokes his interest, whets his intellectual appetite. He tries to enthral the reader by scientific mysteries, as if by the detective mysteries of Sherlock Holmes.

Each work of the author must attract the reader's attention. Otherwise he may lose his reader. Do we ever give a thought to why so many people gather for a good film to cinema theatres? Curiosity is an astounding force, you only need to arouse it.

Instructors have been spoiled in that respect by the fact that students *must* sit at a lesson or lecture. And so the teacher has no incentive to try and interest the student. On the other hand, how much effort goes into making people sit through two hours in the cinema.

Today life involves scientists in this problem and makes them think about the entertaining aspect, accessibility and clarity of treatment. Now that in addition to rank-and-file instructors, this question became of interest for university dons, beautiful books that are really hard to put down appear. Now, for example, physicists are fond of remarkable lectures by Feynman. He is one of the foremost American theoretical physicists, a Nobel prize winner. Also well-known are his beautiful popular science papers. The lectures designed for students have struck physicists as well—so different are they from what has been produced before. Feynman widely uses analogies that seem to be far from physics, he bravely makes simplifications, which later turn out to be invaluable—they help not only to understand the subject, but also to feel it. How cleverly Feynman plays with the student's thought, how expertly, without pressure,

he directs it, how he captivates, attracts attention. And this makes his lectures really "un-put-downable".

Berg concludes:

"It is now impossible not to think about how to write textbooks, how to read lectures—we'll perish, just perish! And bad lecturers should be fired, let them find easier work or prepare a real course, profound, clear and interesting. We should introduce free attendance at lectures. It will automatically sort out the ungifted and make lazy bones catch up with the rest."

In 1963 at Cambridge was held a congress of mathematicians, at which was discussed the possibility of producing a maths curriculum which would begin in kindergarten and last until the students graduated from high school. The level of knowledge provided by that curriculum must correspond to the standard level at the best British university. The idea of creating such a curriculum appeared after preliminary tests at schools and kindergartens. And the experiment yielded startling results: three-year-olds could write and read, seven-year-olds understood the basics of economics and algebra, ten-year-olds were discussing Relativity, twelve-year-olds were at home with higher mathematics, and seniors were dealing with problems of theoretical physics at a university level.

And this was all a result of carefully programmed instruction, which took into account the individual features of school-children, and the material was presented in vivid and exciting form, when the programme stimulated independent search.

This experiment proved once more that a child can be taught anything if he is taught correctly, if the instructor discovers a way of encouraging the schoolchild to think actively, if he finds a curriculum that is adjusted to suit the interests and abilities of the child.

The fact that a child is taken away from outdoor games and put for half a day in stuffy classes, may evoke a steadfast dislike for learning. And to compensate for this, the teaching process must be more interesting than any game. Otherwise, learning will be like visiting a dentist. This is because the child has not yet developed the feeling of conscious need. Well, and adult who has not developed this feeling may also present a problem. Professor Bin, the dean of the therapy department of Iowa Univesrity, exclaimed

pathetically: "No speaker, whatever his energies, has any chance of defeating the sleepiness of the listeners!"

And Darrow, comparing the work of actor and instructor, is led to conclude that the actor is better off: he is an expert in keeping in touch with the audience, he has some faculties and experience, he is pronouncing words checked many times by an experienced director, etc. etc. On the contrary, the instructor or lecturer is generally no expert in rhetorics, his material normally calls for unrelenting strain of attention on the part of the audience who frequently seat in inconvenient chairs in a stuffy hall.

...This all would come to mind during frequent and heated disputes of psychologists and instructors, who were trading various teaching techniques. There was not a shortage of opinions. In those discussions Berg's position was the most difficult one. He at times had to disappoint dozens of people when he saw that they were following an irrational, ineffective path. Berg was eager to modify the entire course of pedagogical practice in the Soviet Union, to guide it in the right direction, to join forces of sciences. He could not boss it, push around, require conformance to common viewpoint on the teaching process and tasks of programmed instruction. The matter called for careful examination. First that, then persuading, urging.

But it was an extremely delicate thing—to prove to a team of investigators who were concentrating on a theory that they were wrong, that their method failed to solve the major problems of instruction. That was so difficult—to urge them to give up the approach they had long been pursuing considering that it was right, that they would make enormous contributions to instruction. Berg tried to be objective. Arbitrary decisions in science are out of place. After all, he was no psychologist, and Leontyev, Galperin, and others, were professionals. Maybe they were still right? What would other experts say? And he read their works again and again, discussed them in the Council. He was stubborn—he had either to see his mistake or to prove that he was right.

...Science will always move on to the truth on several fronts, by several paths. But the paths are bound to intersect.

"Schools of thought, which now seem to be different, must focus on the same picture..."

"The same"—that was what Berg wanted.

"We should not forget the words of John Conent, president of Harward University, 'The ideological war with Communism must be won at schools'. We should hurry and step up the pace in one of the acutest forms of competition —the competition of ideas and intellects."

Dispute about a Beard

It was exceedingly difficult for a nonspecialist to follow the reasoning of the arguing psychologists. Only Galperin's group seemed to have a concept, clear, concrete, ready for use, and only that group bravely and decidedly put forward a specific teaching technique: take it, introduce it at schools, rationalize the teaching process. And what could the opponents put against it? A dream? Like it or not, an adaptive machine was a dream at that time. Berg, Zhinkin and other enthusiasts of the cybernetic instructor called everybody together under the banner of their dream, offered to join forces with the view to solve the main problem, the problem of programmed teaching. They maintained that Galperin's method was just one of the many teaching methods, but it did not provide for an individual approach to each student, since that method was not programmed instruction in the modern sense of the word. That was not the most effective and optimal teaching technique. But the Galperians believed in it, they did not want to forgo it, they defended their work stubbornly. Let us listen to the dispute of the scientists, they frequently were a bit too hot, sometimes biased, sometimes even humorous. Discussions grew especially vigorous when they included Zhinkin, a brilliant polemist and impassioned adherent of adaptive teaching machines. He was especially sarcastic proving the inadequacies of the mental action method.

"How can you preliminarily prescribe the order of actions for the brain of a student, if you have not the foggiest idea of how nature is operating that unique tool?" he attacked Galperin. "You don't know what occurs within the student's head, and nobody knows, but you pretend to know. You make a list of actions that, without a moment's hesitation, the student must carry out, and consider them to be the most direct path to the aim. But whence such self-confidence? We are not even that aware of anatomy

and physiology to say how a man walks, what he switches on and what off. Man learns to walk himself—but how?—an enigma. Man moves his fingers, having no idea of how his nerves control his muscles. He sees without understanding how an image is coded and transferred from his eye to his brain. He digests food, not realizing how his stomach is functioning. Isn't it so?"

Some of those present have a bewildered appearance: indeed, this is very obvious, but we somehow do not give a thought to it.

"And all the more so we do not know what goes on inside the head," Zhinkin goes on saying, "We do not know and even try to teach something to our poor brain. Happily, the brain is an adaptive system, capable of being taught. But we may mishandle it by teaching it 'to walk upside down'. Well, the brain can be forced to learn in various ways, but our task is to find the optimal one. And the best approach so far is to lean on nature, as we do in walking."

Galperin is furious:

"How is it, on nature? A student may think of God knows what. You just cannot predict the result. And we must specify to him what precisely he must do."

Zhinkin wouldn't budge:

"No, the result will be the one you want. A feed-back! A teacher or an adaptive machine will check what the student has got, and prompt him if he was wrong, 'You have to correct here'. The student will solve one problem after another, progressing from the simple to the complex, and he himself will advance step by step. Whatever the teacher said and whatever he didn't say, the student's brain will always produce something peculiar, drawn from his previous experience. But for 'this' to emerge, he must be said something, and then be checked. But how 'this' emerges—that's a mystery, but 'this' will emerge, by all means. A student is given a problem, he starts solving it and sees: it can be solved this way or that. But the most important thing is what takes place in his head in the process. The student is always happy with such a transition—and this is exactly the path of small discoveries."

Galperin said sarcastically:

"One will surmise, another will not."

Zhinkin:

"You'd see to it that he does surmise. We've got one po-

werful tool—feed-back, a constant contact between student and teacher, a dialogue. Its objective is to check the path followed by the student's thought. But let the thought choose the paths for itself. And it is its ability—independence, ingenuity, uniqueness for each person—that deserves especially close attention. We've no right to bully it, to confuse it until we know with certainty what occurs there in reality. Well, when the teacher is facing a huge audience the feed-back with him is incomplete. But if I could speak to each student, then depending on his response modify my explanations, and then again talk to him, and again adapt to his way of grasping, if I could programme my lecture a dozen times, when I've got forty listeners (that is if I were a machine)—that would be one hundred per cent programmed instruction. The specific feature of the new approach lies precisely in that we plan our instruction for each student, adapt to each student. Programming leads us to each student working independently, according to his abilities, with a teacher or an instructive machine. But each is thinking to himself! Reflects! And if you keep hammering away at the student: make this, make this, make that, you'll inculcate some habit in him all right but you'll never teach him to think. You dictate to him some actions, he carries them out: tra-ta-ta, tra-ta-ta, and that's all. And you call this teaching. You might as well say that you can teach a baby to walk by writing to him what and how he is to activate his muscles?"

All the twenty people gathered in the small office of Berg's laughed.

"Just as it might be the case with the centipede," Zhinkin continued the joke, "Have you heard this one? Once it's stopped to think which leg goes next, the twenty-fifth or the thirtieth, and immediately it becomes subject to inhibition, according to Pavlov. It just cannot make a step, for it doesn't know which leg is to be moved next. All its life it ran with never a thought, and now it has stopped to think."

Everybody was laughing, and somebody behind me tells the joke:

"A grandson asked his grandfather, 'Granddad, where do you put your beard when you go to bed—over or under the covers?' 'Don't know,' answered the grandfather. When going to bed the old man became thoughtful. He put his

beard over the covers—uncomfortable somehow. Under the covers—also uncomfortable. He did not sleep all night."

Zhinkin continued:

"It follows that I've been walking for over 60 years, and have had no idea of how and what I've been doing in the process."

"That's why you walk all anyhow," interrupted Galperin.

"But soldiers and sportsmen are taught to walk properly."

"But this all has been invented: the French pace, the Japanese pace, and the way the Nazies marched. What's been invented is readily taught. But I'm speaking about natural movements. They occur unconsciously. Man also thinks unconsciously!"

"And it is possible to think consciously."

"Without being aware".

"It's not allowed!"

Everybody laughed.

"You'll just spoil everything, just as with the centipede," repeated Zhinkin.

"You thus throw a man into the water and say: learn to swim?", again asked Galperin, "But swimmers are taught!"

"They're only taught the invented styles: breaststroke, crawl, butterfly, and so on. You cannot teach a motion as such; at any rate till you learn how it comes about. We move about following some strict rules, although we do not know which rules. We think and don't know how. It's a bit too much, to compare thinking to swimming. And for both processes we issue a scheme of actions, a list of 'mental actions'. These are disparate things."

"Be it with a teacher or an adaptive machine, but a student must think on his own, without constantly referring to some scheme of actions. Only then will we get the desired result," insisted Zhinkin.

"If any," objected Galperin.

"And have you tried?"

"And you?"

"Of course," answered Zhinkin.

"And how do you do this?"

"Quite simply. I compile a pertinent program, and if I find out that the result is inadequate, I do everything again, some other way."

"And we do the same. But suppose you've worked out a program, what's it like?"

"But I'll never finish it."

"How come?"

"It's going to be continually improved."

"I see, but at some stage it'll be sufficiently finished to be given over to practitioners? In what form will it be then?"

"In the form of programmed material."

"Broken down into steps?"

"Exactly."

"And where does self-control come in?"

"It includes everything."

"Then we've got complete coincidence."

The dialogue was vehement, externally both opponents were quiet, but one felt that this is the quietness of a volcano. Any second an eruption might come. A colleague of Galperin's even stood up, when both sides sort of came to an agreement.

"How can you agree? Everything in our methods differs!" And the audience sighed happily:

"Agreed! At last."

In the heat of the dispute they even overlooked the irony in the words of the opponents, the guile of the agreement.

And then...

The Volcano Has Awoken

"Only you have no programmed instruction, that's the point," noted Zhinkin with an inimitable intonation, looking serenely at the ceiling.

"My goodness!" sighed Galperin with annoyance.

The scene was so comic that everybody laughed again.

"Your method contains what you yourself object to—grinding and cramming" insisted Zhinkin. "And it must be boring for a student to fiddle with cards. He should be talked to! I believe that a controller of the behaviour of man is language. Otherwise man would have lived as an animal. You can teach a man to speak an unfamiliar language if you start with the simplest things. Say, to point at a telephone: 'This is a telephone.' 'Where's the telephone?' 'Here's the telephone'. In this way he has learned several words and is now able to speak about a telephone. Now you complicate the constructions. 'Here's a black telephone, it's heavier than the green one'. And so on and so forth. By

complicating the dialogue you can teach your companion to speak a foreign language. Any teaching must be viewed as language teaching: mathematics and physics can be grasped more easily if one starts with the simplest elements. You'll only have to be able to single them out and to explain."

"Coming to school, a child has already absorbed some notions, and so instead of a tedious program of writing the figure of eight you normally chuck him, he can with more ease master the eight if you ask him, 'Have you seen an onion?', 'Yes, I have.' 'And two onions? Bring one close to the other and you'll get a figure of eight.' But instead you pile up for him an entire programme of five actions. He should be talked to in a language familiar to him and you can then rely on his gumption all right."

Zhinkin went on to say: "In his time, Ivanov-Smolensky, a student of Pavlov, studied conditioned reflexes working with children, but he was disinclined to use language. Pavlov asked him: 'Do you speak with the children?'. 'No, we don't'. 'How come?' 'According to our technique we mustn't speak to them.' "Why?' Pavlov was surprised, 'Then it's unknown whose conditioned reflexes you study: human or animal.' You should speak to a child. You ask 'Do you see this?', and he answers 'I see, I understand'. Of course, he sees, thinks and understands much."

Berg interrupted and, as always, added something personal:

"You know, I keep drawings of my daughter since she was three. This is an instructive, interesting thing. A far cry from her drawings of today. At first some chaos. She is drawing some rubbish and says 'a house'. But this is no house, just some tangled coil of wire on paper. And then appear windows and doors."

"Feedback," supplied Zhinkin.

"Exactly. The child's conscience is taking shape, she learns to observe, at first it seems to her that what she draws is a house, but then she sees that a house looks differently. She draws at first some bubble and says 'This is mamma'."

"And then sees: mamma is different," continued Zhinkin.

"The child is talked to: 'Where're the mammy's eyes and arms?' Language is a great thing. And we've got the question: what must the teacher say to teach a child something?"

Galperin listened grudgingly, this all went against the grain of his theory:

"We can talk up so much."

"No need of talking much here," came Zhinkin's reply, "no need of overtalking. And of undertalking. The thing is to say what provides a maximal result. Of course, you can even give the student the graphic image of the eight and say that it's an eight. You can draw graphs of sorts, or networks (an allusion to an earlier discussion, when Galperin was long describing a program to be followed by a student to learn how to write figures)—but that's breaking a butterfly on wheel. Why? A sense of measure suggests: before writing an eight, one should learn how to write other, simpler things, such as sticks, circles, and then to learn to connect them. One should start with the simplest, just as in learning a foreign language."

This argument went to prove once more that there is only one common sense. There is no such thing as a common sense for physics, another one for psychology, yet another one for another field of learning. Zhinkin independently came to the same idea as the 19th century physicist Gibbs. He was said to be a secluded man and only rarely gave lectures. So rarely that each of his appearances was an occasion. Once at a university board meeting priorities in the curriculum were discussed: mathematics or foreign languages. He got indignant and even delivered an entire speech. He said, "Mathematics *is* a language."

Indeed, the discussion of the two vessels is the ABC of physics. At first a child is offered elementary assignments, and then, step by step, problems are made more complicated. When the child reaches the level of the digit of eight, he will already be able to write a six, a five, a four.... The teacher will only have to prompt just a bit for the child to learn to write an eight. Berg agreed with Zhinkin: whatever the teacher says, the child's brain always produces something of its own, drawn from previous experience. But for 'this' to emerge, the child must be told something, and then checked. But how this emerges is a mystery so far, but it inevitably emerges.

Both views converged only at point: for the child to understand something, he must do some actions, and these actions must be guided. But how? And here started the differences. Galperin blamed Zhinkin for letting the thought

process go as it pleased, and controlling only the results: whether or not the student had understood. Galperin called this way spontaneous teaching (just as spontaneous is the teaching of motions). He held that his team, using a detailed scheme of actions, not only controlled the grasping from the results, but also planned the entire procedure. They formed knowledge.

"But you have no adaptation to each person," joined in one of the psychologists.

But Galperin insisted:

"This is not necessary. This is an exaggeration. You are talking about abilities because you blindly rely on what occurs in the student's head. And as you do not form this, you end up with a spread in abilities. But we place teaching beyond the framework of individual powers. Individual differences in acquisition of new skills result precisely because the very path of realization of an action is not pre-set, but is found by each person according to his own powers. When this path is pre-determined and we control, not only the final result but the progress along the path, you remove the influence of individual powers."

To make all equal, even at the level of A-children? What about Einsteins, Beethovens? And how about "from each according to his abilities"?

"Of course," Galperin corrects himself, "the role of aptitudes is not done away with. You're welcome to show your talents in everyday life."

Zhinkin shrugged, perplexed:

"I don't understand you."

Passions became so heated that Berg decided to interfere:

"Friends, please, don't take offence, we should sort it out together. I consider it a national disaster that Pavlov's disciples have quarreled. But we should cooperate in order to work out the correct position. We are paving the way. We have no right to waste time on mistakes. But, please, don't let us take offence."

A Parable About an Elephant

Once the discussions at the Council for Programmed Instruction on the issue of mental actions lasted for three days. At first in the duel with Galperin, Zhinkin was the

main target. On the third day, after the two had tired a bit, the duel was continued by Berg and a Galperin's colleague, Talyzina. This was really some kind of verbal joust: a passado, another passado, one assaults, the other parries, and so on. And if Galperin and Zhinkin are people of relatively quiet dispositions, and their argument was conducted on more or less diplomatic terms, Berg and Talyzina are both expansive and less reserved. And to dispute with Talyzina was not easy.

Talyzina was absolutely sure of the infallibility of her position. And Berg seemed to have forgotten at times that his opponent was a lady. Both were talking excitedly, spiritedly, both were putting a lot of "heart" into it.

"No, but what have you contributed to science by your theory?" Berg continued in this vein, "What you suggest is an awfully primitive thing."

"It is primitive all right, but you haven't grasped what we wanted to say. These operations are primitive, but they lead you far," noted Talyzina sadly, like one who is not understood.

Berg did not ease up:

"But what has this to do with programmed instruction? How does your system allow us to improve the efficiency of the teaching process? What fundamental ideas underlie your approach?"

Here some fuel was added to the fire by Professor Freidzon. He was an old student of Berg's (now head of a chair at the Leningrad Electrotechnical Institute). He arrived in the middle of the meeting, but he had known Galperin and co. and their theory for a long time. His temperament matched those of the previous speakers.

"What you say," he said, "is a product of your imagination. I don't believe you, I don't believe your case histories. You've improvised your conception and fit practice to it. You're prepared best of all here in this respect: you've chosen cases that support your viewpoint, and on the surface of it they seem to be convincing. But this does not convince me. Another man may come, he will tell about another theory, will furnish other examples, and so on indefinitely. You're not making science, but inventing another, more or less successful teaching technique. And we are interested in a science of human thinking. Science! We'll have to stage experiments that would enable us to produce

a model of the mental activity of man, and only then to use it to check which technique is the best. And what is your initial model? Have you got any model?"

"Of course," Talyzina seemed to be hurt, "we believe that thinking is formed not all at once as an internal process. At first we'll have to produce an external model of teaching, a series of procedures to be written on a card, and with the help of a system of transformations to transplant them into the mind."

Freidzon shrugged:

"This is no model of human mental activity, these are your inventions. And we should think about what experiments are to be performed to understand how a man thinks. And only then to decide how to construct the teaching programme, so that it would not contradict the logic of thinking but help it. Why do you think that your way of teaching is efficient and optimal? But then, is it the best one of all? Not among the first five or ten methods known to us, but in general? Our task is to choose the best way of understanding. And not only from among those we know, but absolutely the best. And here, in my opinion, we are dealing not with the wood, but with a tree. We've taken a tree and want from it to make a judgement of the entire wood, but the tree may be not typical at all. It may be old, dry or, on the contrary, immature, crooked, rotten. But we are interested in the entire wood. In this case, in human mental activity, psyche. But this reminds us of the parable about an elephant. Seven blind people came up to an elephant and started an argument: what is it? One touched the elephant by the leg and said, 'An elephant is a pole', a second one touched it by the trunk, 'An elephant is a hose'; a third one, by the tail, 'An elephant is just a rope', and so forth. We are interested in psychology!"

Talyzina did not withstand the pressure of these vehement onslaughts:

"But what does that mean, interested in psychology? Psychology consists of individual actions."

"Why of individual actions? What does that mean 'psychology consists of individual actions'?"

"Yes, not of God knows what—just of individual actions."

Turmoil began, with each crying out his or her opinion, a sort of chorus, but the soloists hold the chorus in check and were heard again:

"But I believed naively," said Berg, "that psychology is a tangled complex of the entire experience of a man, such that it reflects his physiological state."

"That is your mistake," objected Talyzina, "psychology responds to information about external processes, and it reflects the external actions of a man. It is these actions that we are called upon to organize in such a way that they would contribute to the mental activity of the man. A human being is born with zero knowledge, isn't he? Therefore, when I want to have some knowledge here (Talyzina taps her head), I'll not say where, so that we won't have it as in the children's game 'don't say yes or no, don't name black or white': I must think about what external actions the student must go through, for them to be reflected in his mind. And this is the most difficult thing in producing programmed material. The simplest example is counting. Mental arithmetic is taught using fingers and sticks."

"And how about history and geography, these too should be taught using sticks? And to draw pictures, something should be said aloud?"

'No, one should find an equivalent action. It is sometimes said: one has analytical, intuitive or mathematical thinking. But what does this mean? Everything depends on the actions transplanted into the student's head. Whatever knowledge we want to give a student, he won't absorb it, until he starts doing something with it. And to give him this programme of actions is our task. And we are working on this."

"What have you been doing for the last six thousand years? When I start leafing through textbooks on pedagogy, I'm bewildered, who is mad, the authors or myself? Only one technique reigns absolutely: 'chalk, blackboard, duster'."

"Textbooks are awful," agreed all those present—a rare moment of agreement.

"And all because we attempt to stray away from exact sciences and confine ourselves to fiddle-faddle. This is no science, but utter counterrevolution!" concluded Berg with his favourite phrase.

"This is because exceedingly complex things are involved," stated Talyzina authoritatively.

Berg laughed:

"Eh, complex, that's it!"

"Not 'eh'," corrected Galperin, "but everything is very complex indeed."

There was a small relaxation.

Finally, Berg seemed to have reconciled himself with the thought that Talyzina, Galperin and their theory were real entities. And Berg would not be Berg, if he did not respect stubbornness and devotion to duty. If people are possessed by their theory, he believed, they should be given an opportunity to move quickly from an experimental stage, to prove its correctness or to identify its uselessness by practice.

"What help can the Council for Cybernetics give you? First, let's organize a seminar for instructors where you'll be able to make your reports and pass your method on to teachers, to schools. We'll provide you with the premises and money. Now another question: can you write a text according to your method so as to check it throughout for entire course, not just for individual fragments of a subject? This alone would bring out its positive content and fundamental drawbacks. How long would it take you?"

"About two years."

Berg jumped up:

"Two years? Too long, too long, nothing doing! Do you need people, staff?"

"No, we've already got fourteen people, enough for the time being."

"But we cannot wait so long!"

"But we haven't finished the experimental stage."

"We cannot possibly wait indefinitely! Tell me please, how can I help?"

Followed a long discussion of the practical assistance to that team.

"Look here," said Berg, "I want to have in the Soviet Union a unified programme, a common viewpoint as far as methodological, philosophical and other issues of pedagogy are concerned, specifically on programmed instruction. I want to know, whether the introduction of new teaching means contradicts the principles of Soviet pedagogy? What should be done to help it? After all, programmed instruction is no end in itself; on the contrary, it must perform an auxiliary role, useful for the main task—bringing up and teaching youth. I want to follow the correct line. You do know how many groups we have in programmed instruction, and, my dear friends, there is no agreement between

you. I think we should seek it. Of course, there will always be some disagreements, but the fundamentals must be unified. We cannot progress further in programmed instruction till we see that we do not produce counterrevolution. We must follow the lines useful for Soviet teaching. That's why I gather you all here—you won't gather for yourself—and I will keep gathering you till my last days."

Such a declaration may seem rather gloomy, but gloominess is not in Berg's character, therefore he, as always, concludes with a witticism:

"There's been much to-do here for several days, but everything ended peacefully. So far nobody's had a heart attack, nobody was carried away, nobody fought, there is complete agreement, isn't it?"

Amid the laughter Talyzina noted:

"But you threatened to hurl the telephone at me."

"You don't say so?" Berg was horrified. "Well, then, friends, we've done some useful work. I've learned much from you and prompted something myself, didn't I?"

In this way, by starts and jerks, in disputes and jokes, a new science was making its appearance. At first small streams of ideas were correlated, analyzed, then they merged into a flux of open discussions at conferences and other meetings. And finally, these streams merged to form full-flowing rivers. These were plants, research institutes, design offices, where the science of programmed instruction took shape.

But to reach this happy end a long and difficult path had to be covered. Reconnaissance discussions revealed shaky areas, and even the ignorance of the workers concerned. Many had to return back to square one. As for Berg, he was only stimulated by this. He was confident that cybernetic techniques in teaching were necessary and fruitful.

Berg said:

"It's only the beginning now, like a stage of pregnancy. And it's only natural that some think it's just a fad, a fleeting fancy. Such attitudes only suggest that some of us do not deduce lessons from life. But this must be ended. The machine of pedagogic sciences comes to life painfully. Enormous upheavals are to be expected in that area. Now perhaps it is seen not by all, but future historians will say: the revolution in teaching started in the 1960s. This is one of those revolutions that come not as a whirlwind. This is

a revolution that must possess the might, doggedness and stamina of an icebreaker. It is gaining strength steadily, purposefully, with each day, each hour, each moment.

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An Epistolary Part

Having sat in for many days at discussions and symposia, I succeeded in peeping behind the scenes of the most fascinating theatre, the theatre of thought. Before me were played out dramas of ideas, which accompany any pioneering science, was undone a knot in which were tied audacity and ignorance, fortitude and stagnation, all that is inherent in men of science in much the same way as in members of any other profession.

Discussions with Talyzina and Galperin, emotions associated with other futile attempts, were just episodes from Berg's working days. But the problem of programmed instruction was just one of the many other problems that were coming under the umbrella of the Council for Cybernetics, just one facet of its many-faceted activities. And nearly each section, nay, *each* section of the Council was dealing with topical, urgent problems of modern sciences. And if a problem was still in its infancy, much discussion and controversy surrounded it. And Berg was always in the very thick of events, an anchorman of disputes and polemics. He was still travelling widely, still establishing enterprises and institutes, and still appearing with presentations. Sometimes he sent letters. In one of them he wrote:

"Lately I'm working much on programmed instruction. Fresh materials roll in from many countries and our sister republics: there is no stopping programmed instruction now, and of course it will be improved—at the present time much importance is attached to logical information machines and computers designed for teaching using adaptive programmes. The psychologist Lomov came, the teacher of the Leningrad Electrotechnical Institute Freidzon and scientists from Riga, Tadzhikistan and Uzbekistan, from Kiev and Georgia—everywhere there's much activity!"

And in a short while:

"I'm waiting impatiently for the report of the Ukraine on programmed instruction to be given at the board of the Ministry for Higher Education of the USSR. Much useful work has been done in the Ukraine. And the main thing

is their ever so promising first successes in adaptive computers.

"This all encourages me a great deal. I continue my diligent and painstaking work on a book entitled *Pedagogy and Cybernetics*, which I've been writing three years now. I'll finish it, I think, in half a year or a year, but I will finish it in this world. So far I've put in about two or three thousand hours of hard work with sources in Russian, English, French and German, and have only produced 200 pages, but in drafts I've prepared material for about 500 printed pages. I do not touch on the diagrams, constructions and designs of teaching machines, but only say that it is necessary to come to grips in the most serious manner with the issues of teaching in accordance with the present-day needs and possibilities. To this end, I had to rummage through all the available literature on pedagogical psychology, didactics, theory of information, psychophysiology, theory of games, operations research, optimization theory, control of large systems, and so on.

"This is a large scientific work, it will be exceedingly difficult to accomplish it, but I still intend to make it, if only I have enough strength and health."

And once I received such a letter:

"You'd hardly believe—our successes in the field of programmed instruction are now of concern in the West. I got a fresh number of the French magazine *Enseignement programmé* with a geographic map of the proliferation of programmed instruction throughout the countries of the world. It is said in one of the articles: 'The USSR will soon become the leading country in programmed instruction.' Well, if the Council works with the same devotion, this is quite possible."

Later arrived another letter, long and amazing:

"For several days I've been visiting computer works. What a beauty! This is just fantastic—I'm a radio engineer, but, you know, at some stands I was simply lost, impressed by that complicated, grandiose thing—modern technology. And it is run by young boys and girls. Just callow youth! They come to the factories after schools, they study extramurally at the factories, and just fancy, in a year or two they become grandiose specialists. They were teaching me how to handle their computers. I decided to visit them more often, to be kept up-to-date... This is all very well,

but our sore point remains the same. We are producing all too few computers. Few, very few. We should evaluate the needs and take decisive measures. And we should also think about instruction! I had a sleepless night—what's to be done? So far I've found the only way out—I'll insist on the complex uses of the available fleet of computers. My idea is as follows: if computers are still all too few, we should put them to more effective use. They should be utilized like a grandmaster playing simultaneously with dozens of chess enthusiasts.

"We should consider creating a collective system of computer utilization. Losses of computer time, especially with large powerful computers, are expensive. And so, let enterprises that use computers for their main purposes offer their 'superfluous' time on lease. We'll use it for teaching purposes. This time runs into hours, or into seconds—downtime, readjustments, etc.—and in these seconds a computer will be able to make plenty of operations. A computer sometimes needs a split second to solve a complex problem. That's why we should try, without detriment to the main work, to use computer time to serve other customers. These may be other businesses, schools and institutes, and even individual persons—scientists, engineers. Tomorrow I'll approach the government about this issue.

"The more I think about that 'grandmaster' system of computer utilization, the more I like the idea. Such master computers can be used through terminals to serve customers hundreds of kilometres away. The benefits are derived due to the difference in the speed of operation of the human and electronic brain. While a man formulates his task for the computer using key boards, the computer will have enough time to serve a customer from hundreds of kilometres away, and return its attention to the first customer by the moment the problem will be formulated in its final form. If a customer is using the computer intensively during an hour, the computer will be able to carry out all the work by switching on several times for fractions of a second. With such a system the computer functions continuously and nobody among the users will have pangs of conscience that he is wasting valuable computer time, and he will not be afraid to lose money by paying for the unused time.

"I'm sure that putting that cheap and ordered system of computer 'first aid' into practice will make it possible to

expect in the nearest future, an explosion of discoveries, an intellectual jump of mankind. Such a step in the development of electronic computers is more important than space research using rockets. It's even difficult to visualize the unheard-of progress and those changes in our lives, the outlines of the world that is approaching us with an indescribable speed."

Epilogue

With this unrealized dream of Berg, I shall interrupt my story about one of the many scientific problems that occupied his mind and heart during his last years. But how many of them were there in his life! The problems were not becoming simpler, they were growing with science. They required an ever wider scope of knowledge, encyclopaedic erudition, volcanic managerial energies.

I heard such opinions: Berg was a jack of all trades, Berg had too many irons in the fire. Nothing of the sort. It is difficult to come across a man who was true to one calling, and so invariably remained his own self. Berg was devoted to his initial profession, that of navigator, trail-blazer. And like a navigator, each time he plotted the ship's course, be it in electronics, radiolocation, cybernetics, or programmed instruction. And like a navigator, he studied the situation and shaped a plan of actions, carefully prepared an operation. His task had always been the same—to bring the ship to her destination.

In his last years Berg was possessed by one of the most important problems of our century, the forming of an intellect. He was looking forward to having man improve his intellect, and use his powers for the benefit of the general cause. We will see the development of that problem—it is happening before our eyes, today.

Its solution will help each individual to reach his or her prime. Each of us is, in essence, an unripe fruit: because of our own laziness or circumstances, defects of upbringing or unpredictable influences of milieu... Not everyone has enough will and self-possession to develop independently the most valuable assets of one's character. Most of us just "go with the flow". And not all of us have self-perfection abilities. We still waste all too much time and effort and are often unaware that civilization can create unprecedented

conditions for the growth of personality, for self-perfection, and that this is essentially the meaning of the existence of mankind: each human being should develop into a fullblooded personality.

To achieve a perfect crystal, chemists place a tiny nucleus into a suitable medium, under especially favourable conditions. Human society has not yet succeeded in attaining similarly favourable conditions for developing perfect personalities from its human nuclei—children. Only some of us manage to realize our potential fully. And the lives of these people, the secrets of the crystallization of their personalities are always attractive.

And this secret is often no secret at all. Much depends on ourselves, on our efforts, on our perseverance, on our devotion, on our understanding of the meaning of life.

Having been born into a gentry family, Berg had chosen the path of a hard worker. Having started with the modest profession of navigator, he succeeded in developing his knowledge up to the higher spheres of intellectual activities.

Berg, of course, had also had his share of good luck. He was born at a good time—the Great October Revolution had helped him to change drastically his career and taught him to live with the interests of the century, to grow with them. Yes, Berg had been formed with the century, during the most stormy period of a stormy century—he had seen the early cars, the early cinema, the launching of the first artificial satellite. He participated in the design of the early radios and early cybernetic machines. His horizons were so wide, the sphere of his activities so diverse, that if Berg had lived in another time and in another country, he could have been counted among those lone wolves, whose lives and careers are of interest as exceptions, as phenomena. But in our days such explorers as Berg are no exception any more. They are not that numerous, but they are typical for the science of the new society.

Berg kept self-improving throughout his life, with an enviable doggedness and constancy. Obviously, his relation to his own life as duty to society had led him in his later years to the general problem of the upbringing of a human. Berg believed that it was necessary to educate oneself in the most serious way possible, to control the processes that shape human personalities, to cybernetize mental development.

It is in this that he saw the pledge of the realization of an ideal human society, a communist society.

...Once Berg was invited to a meeting with people of art. Actors, directors and writers were interested not only in the latest achievements of science and technology, but also in their own, purely professional issues concerned with representing people of science. And so actors were wondering how one should represent a scientist on the stage. In what way did men of science differ from members of other professions, and how was this to be conveyed to the audience? What was the key to the character of the present-day researcher?

"In science," said Berg, "this is, above all, his work. Well, a scientist does not stop being a personality, or a member of a team. But in social aspects as well, one sees the main core of his existence—his work, his science, the fruits of his intellect. Without penetrating into this, one won't be able correctly and profoundly to picture the personality of the scientist both on the stage and in a work of fiction. Only deep insight into the essence of scientific task, which absorbs the mind and heart of the scientist, only the penetration into the intellectual stratum reached by the scientist's mind in search of truth may provide the key to understanding his personality."

That is why in this book I tried to pass from one problem to another, seeking to reach the modern level of scientific outlook. In that way we encountered not a single law, named after Berg, not a single striking discovery that history will attribute to him. But we have got acquainted with a new type of scientist, with a new kind of scientific activities. Planned development of Soviet industry, science and technology begot the scientist-organizer. Such was, for example, Academician Ioffe.

Soviet physics justly prides itself in the achievements of Abram Ioffe in semiconductors and dielectrics, optics and electricity. But the main contribution of Ioffe was the remaking of Soviet physics from a science of academia into a science of teams. He was handpicking gifted young people and molding them into bright theoreticians and experimentalists. He was establishing scientific centres, organizing and dividing institutes, just like a gardener grows and then divides a fruit-bearing plant, providing ample nutrition and

light for the fragments in other, carefully prepared parts of the garden.

Berg was a scientist in much the same way. His personal contribution to radio, navigation, radar and cybernetics is sufficient to win fame for many. But the duty of a citizen and explosive temperament demanded that Berg constantly sacrifice his personal scientific plans for the sake of social and state interests. Battles instead of arm-chair studies, lecturing as a form of self-education, intensive educational activity, which unfortunately allowed too little time for laboratories, his long-term naval radio effort, extension of radar and cybernetic knowledge, when theoretical studies were hidden by heaps of office papers, instructions and drawings.

Now that science has become a powerful productive force, the role of scientific administrators is ever growing. There are established special organizations providing guidance and planning in scientific research and application of the findings to various fields. In the Soviet Union this office is the State Committee for Science and Technology, whose head is a Deputy Chairman of the Council of Ministers of the USSR. Similar organizations exist in many countries.

... Berg always stressed the role of cooperation and team spirit in modern science and technology. He was perhaps a bit partial to electronics, as a bridge between most scientific disciplines, between seemingly disparate branches of technology. He liked to bring out the direct connections between many major scientists and radio. The late president of the USSR Academy of Sciences, S. Vavilov, an eminent optician, served in a radio-telegraph unit in World War I. One of the fathers of modern quantum physics, Louis de Broglie, also was a radio-telegraphist, just as Academician A. Mints, one of the prominent Soviet radiophysicists. He is remembered as a producer of the most powerful broadcast stations. His long acquaintance with Berg had grown into a friendship during the radar period of Berg's career.

Radars and accelerators, who produced them? History of science is more fascinating than any novel. Its heros are real men. Neither radars nor accelerators were possible without the klystron designed by N. Devyatkov and the magnetron designed by M. Bonch-Bruevich. They could not have been built without the discovery of the laws of propagation of ultrashort radiowaves in free space and in wave-

guides, which had for the most part been studied by B. Vvedensky and co-workers.

... Berg liked the history of science and considered it valuable in making predictions. He considered the contradictory path of the development of radio to be instructive. From short waves to long ones to provide the range of action, and back to short ones, again to increase the range, and to yet shorter ones for radar, and again to long ones for radio navigation. Radio-location was plagued by the struggle between pulsed and continuous operations. Everything was good in due time. The pulsed radars of Yu. Kobzarev and co-workers came on time. They were in use during World War II. Their descendants are in existence now and will exist in the future. But continuous radiation, advocated by Mints back in the 1930s, has not left the scene yet. In many cases pulsed radars have had to make room for continuous ones.

In a short period of time the history of science saw a curious revolution. Radio, hardly out of its infancy, permeated science, technology and household. The several dozen founding fathers of radio also went their separate ways. Radio, like any other branch, became specialized, and it seemed that their careers would never cross again. But, all of a sudden, cybernetics entered the world of radars, accelerators and aerials. Without a modern computer a radar would now be impossible. It would be just a passive witness of events. With today's speeds, to control an aircraft, or a missile, the radar and the cybernetic machine must be a single whole. This ensemble includes cybernetic trainers, involved problems of neurophysiology and programmed instruction, the mazes of man-machine communication. Cybernetics reunited all the spheres of radio, reunited friends of long standing.

Berg liked to say that he was a rank-and-file researcher, but he had a good luck with teachers, colleagues and disciples.

"Whatever I managed to do I did not alone," said Berg looking over the manuscript of this book, "Many colleagues and friends, whose contribution to science and technology is more important than mine, haven't even been mentioned or their works have not been described in sufficient detail."

Actually, the book contains nothing or nearly nothing about scientists and statesmen with whom he met and

worked, if those meetings and cooperation had no direct consequence for his career and his life. Otherwise the book would not be about Berg.

... Anniversaries, when a man is sixty and even seventy, have always seemed to me to be somber events. You can imagine my surprise when I arrived at a noisy gathering. There were so much joking and laughter, so much youthful ardour!

Merry-making had reached its height when at the end of the function the hero of the day was given a striking thing. A man rose on the platform and put in front of Aksel Berg... a cybernetic machine. This was a special model, which in the opinion of its authors, students of a technical college, was needed for an Academician. The machine gave answers to the questions: "Can a machine become an Academician?" or "Can an Academician become a machine?"

To the last question the machine, amid laughter, gave the answers: "Yes, he can, if he becomes a member of many commissions", or "Yes, he can, if he works like an automaton", or "Yes, he can, if he is used to repeating other people's opinions". Aksel Berg immediately, there and then, rushed to improve the machine.

Such was the seventieth birth-day of Aksel Ivanovich Berg, a man full of buoyancy and energy, always sparkling with joy, humour and benevolence. Therefore, the occasion was a far cry from those solemn traditional dull parties, those gloomy last balls.

The throngs at the Moscow Club of Scientists resembled a meeting of alumni or old war veterans. No wonder. Many of those who gathered there had been connected by common work and common interests for three or four decades.

On that day Berg received more than 1 500 letters. And when journalists, having gathered around Aksel Berg, showered him with questions, he said, glancing at the heap of letters:

"My life? Well, it's here...".

Somebody took a letter at random: "Dear Aksel Ivanovich. This morning I saw *Izvestiya* with your portrait, with a description of your enormous services to our Motherland. I hardly recognized you in that picture: there remained something unique in your eyes, high forehead, especially in the decidedness of your mouth, which distinguished you even in the fifth company of the Naval Corps, where I

happened to be an *Unteroffizier* at your table.

"Thousands of kilometres separate us. In my garden at Nice, oranges and lemons are ripening, beautiful roses are in bloom, but in your Moscow, according to today's *Izvestiya,* in Moscow where I was born, 12 degrees below zero and snow lies blue on the roofs.

"As far as I remember, you graduated from the Corps as a *Feldwebel.* I remember Medovikov, Korolkov, Kartsev, that small boy with a big head, who became an airman and died heroically after a number of personal victories in the Gulf of Riga, and the next day a German aircraft cast at the place of his death a wreath with a Russian inscription to commemorate the hero. I remember Tankov, Dubinin, the charming Chizh, whom I encountered later in the south of Russia. Where are they now, those dear boys, with whom we drank tea from large mugs with two-headed eagles and good loafs and like brothers drank excellent kvas from a wooden jug at lunch and dinner to the accompaniment of our rather good orchestra.

"Even at that time you were distinguished by us as an outstanding youth, and I know that you have earned all manner of praises and decorations and laurels. The happiness of soul and heart is enormous if one succeeds in leaving behind in life something really useful for mankind. You are the only person whom I write to in our Motherland after the many decades, the only one, save for my mother who died in Sevastopol after she refused to leave the town....

With sincere respect
A. P. Pavlov (graduated in 1911)

The letter breathed with pain and suppressed anguish. Surprised, we glanced at Berg.

"I remember him excellently. When we were boys we studied together at the Naval Corps, served together on the battleship *Tsesarevich* and fought together against the Germans. I replaced him in 1916 as a navigator on the British submarine E-8, which joined the Russian Baltic Fleet. And then our paths diverged."

Pavlov fled from revolutionary Russia. Berg, a nobleman and a son of a czarist general, sided with the revolution.

"An unexpected pleasure: I got a letter from the former junior navigator at *Pantera,* Alexander Krasnov. And I

thought that he, like many others, was no longer with us. Or here..."

"You are greeted and congratulated on your seventieth anniversary by the former commissar of the Headquarters of the Petrograd naval base and the extraordinary commissar for the disarmament of battleships, Yan Platten. I looked at your photograph and in it I saw the starry paths of the revolution along which we were marching together..."

Among the letters were merry ones, with comical reminiscences, sad ones, business-like messages, long and short, just several telegraph lines. And behind those letters was a long, stormy, eventful life.

"The eighth decade! In essence, not that much," concluded Berg...

On 10 November 1978 Aksel Berg was 85. That day, just like nearly all his days since his younger years, started at 5 o'clock in the morning. At 6.00 he was already at his desk. He always believed that three morning hours were worth five afternoon hours: the head is clear, the telephone is silent, most concerns are still sleeping...

In the last years, his concerns became more intricate, more irksome. They never fell asleep, staying with him through his wakeful nights, and waited for him after his short sleep. Energies were ebbing. He underwent several serious operations, one after another. After especially difficult work, he experienced heart-seizures. But when, after them, he would turn up for breakfast clean-shaven, in his glittering admiral's uniform or an elegantly austere suit, his people sighed with relief: it semed to them that the yesterday's attack was pure chance, the worst was over. And his doctor was struck by this manifestation of human tenacity. He said, "Berg holds out by fortitude alone."

His 85th anniversary was marked by hard work. Time was posing ever more complex tasks before the Council for Cybernetics. Cybernetics found its way into all the pores of our modern life in industry, technology, science, agriculture. There was no sphere of human activity where cybernetics would not do wonders with its ability to find the most efficient ways of progress. But these wonders had to be directed, programmed, realized.

The strategy and tactics of the victorious march of cybernetics was developed by the Council for Cybernetics. All the nerves would converge at Berg's office.

He understood more clearly that the Council would have to be reorganized and reinforced to be qualified to handle more grandiose and responsible problems. The struggles for cybernetics were the past, ahead lay the struggles for progress using cybernetics. It took an experienced navigator and a battle-seasoned commander to make the most effective use of the huge army of scientists, engineers, designers and workers, of the huge arsenal of technology at the disposal of the science of control.

And again, like in his younger days, Berg was burning the midnight oil. The old commander was thinking of how that army could be led to the victory by the shortest and quickest path.

Berg was paying special attention to the mathematical section of the Council. He regarded it as the brain centre of the cybernetic empire. It was the first candidate for reorganization. Aksel Berg brought to the meeting two bags of materials, which he had been preparing for the last half-year. He forgot that he was seriously ill.

In that meeting Berg spoke for an hour and a half. It exhausted him.

In the night an ambulance car brought him to a hospital. For two weeks he fought for life. When his conscience returned he was again full of concerns, drew some diagrams, argued with opponents.

On 9 July 1979 he was better. He bid farewell to his wife. Then he said that he was tired and wanted to sleep. It was 9 o'clock in the evening.

A nurse remained with the patient. She was listening to his quiet breathing, and watching the peaks on the electrocardiograph.

Suddenly the peaks disappeared, and there was just a straight line...

All attempts to restore the functioning of the heart failed. No miracle occurred this time.

Beside the dead Berg lay a small red note-book, the last of his diaries. On an open page there were plans, plans...

I thought then, plans that are not destined to come true.

But life goes on. These plans do come true. Only without Berg.

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